TRANSITIONS IN MEDIEVAL MEDITERRANEAN SHIPBUILDING:

A RECONSTRUCTION OF THE *NAVE QUADRA* OF

THE MICHAEL OF RHODES MANUSCRIPT

A Thesis

by

VINCENT NICHOLAS VALENTI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

August 2009

Major Subject: Anthropology

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Approved by:

Chair of Committee,	Luis Filipe Vieira de Castro
Committee Members,	James Bradford
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ABSTRACT

Transitions in Medieval Mediterranean Shipbuilding:
A Reconstruction of the *Nave Quadra* of
the Michael of Rhodes Manuscript. (August 2009)

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The subject of shipbuilding in the Mediterranean during the Middle Ages is an integral aspect of the maritime history of this region. Characterized primarily by a fundamental shift in shipbuilding techniques, this phase also included significant developments in other seafaring practices. Yet, unlike the preceding Byzantine era, there is a very limited body of archaeological evidence available for study which can be utilized to illustrate these changes. Therefore, one must turn to alternative sources of information regarding the construction of ships in the Mediterranean, such as iconography and literary evidence. Perhaps the most informative and useful example of the latter is the group of nautically-themed treatises and manuscripts composed between the 14th and 16th centuries. The earliest of these to describe ship construction in any detail is the 1434 manuscript of Michael of Rhodes, which will serve as the main subject of study for this thesis.

The primary purpose of this research is to propose a reconstruction of the *nave quadra* described in the manuscript, though this will be preceded by explanations of several topics pertinent to ship construction in the Mediterranean during the Middle Ages. The discussion of such fundamental issues, like the transition from shell-based to frame-based construction and the concept of recording and conveying these processes in a didactic manner, is essential in providing a basis for this study. Once this foundation has been established, it will then be possible to present the reconstruction of the *nave quadra*

of the Michael of Rhodes manuscript. With this background information laid out, the significance of both the manuscript and the *nave quadra* in the broader context of medieval seafaring in the Mediterranean should be discernable. In addition to the proposed reconstruction, this task of elucidating key aspects such as the transition from one construction technique to another and the compilation of written material on this subject will be essential to providing as comprehensive a picture of medieval seafaring in the Mediterranean as possible.

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Thanks also go to my friends and colleagues and the Anthropology department faculty and staff for making my time at Texas A&M University a great experience. I also want to extend my gratitude to my parents for their support during my time in the Nautical Archaeology Program.

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INTRODUCTION

From the perspective of the development of shipbuilding methods in the Mediterranean, the period of time encompassed by the Middle Ages is arguably the most significant era in maritime history. Beginning towards the close of the Roman era, the traditional techniques for the construction of vessels of all types were undergoing a transition towards a radically different shipbuilding methodology, creating the foundation for the introduction of the sailing vessel and the Age of Discovery that would follow. Integral to this evolution was a fundamental shift in the conception and execution of a ship's hull, characterized by the gradual abandonment of the traditionally Mediterranean shell-based technique in favor of the principals of the frame-based method. Though originally characterized as fairly straight-forward, this occurrence was by no means as linear and neat as it is often depicted. Analysis of the shift in hull construction has become increasingly complicated as the field of nautical archaeology makes ever greater and more profound contributions to the understanding of technology of this period. While the evidence yielded by the research done in this field and others has occasionally required changes to be made to certain widely accepted conventions, such as the geographical and temporal distribution of shipbuilding techniques in the Mediterranean, it has undeniably proven vital to a better grasp of the material overall. It has led to a far better appreciation of the complexities of the practice of ship construction during the Byzantine era, rendering a more appropriately nuanced point of view than was previously held due to the limited evidence available.

Despite the far from complete state of knowledge about the adoption of the frame-based technique in the Mediterranean that is currently held, the archaeological evidence has permitted a more or less general understanding of shipbuilding history prior to the Middle Ages transition in construction techniques. The following period, however,

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This thesis follows the style of the *American Journal of Archaeology*.

beginning in the early years of the 11th century, has certainly not benefited from such assistance. After the discovery of the first archaeological evidence of a vessel to be constructed almost entirely with the frame-based method off the coast of Turkey, known as the Serçe Limanı ship, there is a disappointing scarcity of archaeological evidence for the further use and development of this method. This is unfortunate from an historical point of view for a variety of reasons, perhaps none more so than the important advancements being made in the design of ever-larger sailing vessels. With the introduction of northern European types of these ships sometime around the beginning of the 14th century, but possibly much earlier, the typical configuration of Mediterranean ships once again experienced an essential evolution. Combined with the advancements that were taking place in the development of navigation techniques, the copying of the characteristics of the northern European *cog* by southern shipwrights marked the establishment of the basis for western European ship design for centuries to come.

It is at this historical juncture that the subject of this study coincides. Some time shortly before or after the start of the 15th century, individuals with experience in the nautical affairs of the important maritime center of Venice seem to have begun conceiving of a revolutionary new approach to the design and construction of ships. Breaking with the tradition of transmitting shipbuilding knowledge verbally and designing vessels mostly by eye throughout the process of construction, written notes for this purpose started to be compiled. While the idea of a maritime manual in the form of a personal notebook, the *zibaldone*, was known before the Renaissance and had already been executed in the 14th century, the concept of including instructions for the building of ships seems to have been a wholly new innovation. The Michael of Rhodes manuscript, dated to 1434, contains the earliest extant shipbuilding treatise available for study. Aside from the obvious importance conferred by its incorporation of material on the construction of a number of contemporary oared and sailing vessels, this manuscript is significant for its influence on many later treatises. Most of these later texts derived their information on shipbuilding from Michael's text, which was then developed into more technical terms.

Although it is suspected that Michael, too, was guilty of the same action, his manuscript is more than just the copy of an earlier text. It contains a compendium of materials on all aspects of his experience in the merchant and military fleets of Venice, including mathematics and navigation, in addition to a detailed autobiographical account from his enlistment in the Venetian Navy almost to his death. From a purely historical perspective, this information and its implications about 15th-century Venetian society is certainly of equal importance to the other contents of the manuscript.

The original purpose of this study was to propose a reconstruction of the square-rigged sailing ship (the *nave quadra*) described in Michael's treatise. However, upon the examination of the sources for this subject it became necessary to widen the scope of our research, as this initial goal was far too restrictive, especially in consideration of the larger trends in Mediterranean shipbuilding that led up to the writing of the treatise. Therefore, the new aim was to still attempt to reconstruct the *nave quadra* to the extent that the evidence permitted, however this task would now be placed in the greater context of the transitions in shipbuilding in the medieval Mediterranean. This should allow for a more comprehensive explanation of the reconstruction of the *nave quadra* and the historical background of the construction methods used, as well as of the ship type itself. As these technical aspects are correlated with the first writing of a shipbuilding treatise and the broader subject of written culture in medieval Venice, these historical facets will also be examined.

The next chapter will begin this study with a look at the topic of the development of hull construction methods in the Mediterranean following the fall of the Roman Empire. This will include a chronological examination of the available archaeological evidence, while incorporating the subject of design into the concurrent rise of the frame-based method. Chapter III will delve further into this discussion by focusing on the debate over the reasons for the transition from shell-based to frame-based ship construction. It will also look at the progress of the debate itself and how it has changed course according to the discovery of new evidence. In chapter IV we will look at the technological innovations in maritime history first seen in the Middle Ages, such as new types of ships and nautically-themed manuscripts. Chapter V will cover the Michael of Rhodes manuscript exclusively and describe his possible motivations for compiling such a document. The last chapter of the body of this study, chapter VI, will propose a reconstruction of the square-rigged ship (or *nave quadra*) described in Michael's manuscript. The evidence offered by this document will be utilized to the extent that it permits in order to complete this task, though several later shipbuilding treatises, such as the *Fabrica di galere*, will also be consulted. Lastly, chapter VII will summarize the content of this thesis and present concluding remarks.

CHAPTER II
TRANSITIONS IN SHIPBUILDING IN THE MEDIEVAL MEDITERRANEAN

In the study of maritime history and, more specifically, the discipline of nautical archaeology, there exists for the Middle Ages a significant void in knowledge concerning the development of ship construction. This lacunae exists in all three of the basic forms of historical evidence: literary, iconographic, and archaeological remains, though this is most notable in written records and shipwrecks. Pictorial representations of late medieval ships are fairly abundant in and around the maritime centers of Italy, particularly Venice. In most cases, though, this body of evidence is given only a cursory examination or is altogether overlooked. One may highlight various reasons why this appears to be the general trend, the most significant of which is likely the inescapable fact that artistic representations cannot always be trusted to be an accurate portrayal of reality. Yet, when this is taken into consideration, iconographic evidence can provide a mass of information that is usually impossible to find in the archaeological and literary records. For instance, shipwreck remains rarely include details of the superstructure and rigging, but these features are quite often portrayed in artistic representations of ships, sometime with surprising detail.[1] Ideally, iconography should be used to supplement the archaeological and literary evidence, but with the deficiency of the latter two any study of medieval Mediterranean ships is more reliant on visual data than would usually be the case.

Development of Hull Construction Methods

Of course it is important to bear in mind that the apparent dearth of information from this period of time should not be interpreted as indicative of stagnation in the design and

[1] Martin 2001, 4.

building of ships.[2] On the contrary, the period of time from the fall of the Roman Empire in the fifth century C.E. to the late 16th century witnessed to some of the most significant developments in the history of ship construction and design. Coined the "Nautical Revolution" by the Venetian scholar Frederic C. Lane (in specific reference to a series of nautical innovations around the opening of the 14th century) this period laid the foundation for the full-rigged ship integral to the commercial success of the 16th through 18th centuries.[3] From the perspective of the methods used in the construction of a ship's hull, the most profound and comprehensive development was the shift from shell-based to skeleton- or frame-based construction. The former method was used for the earliest seagoing ships, at least as far as can be deduced from the available evidence, and implies that the main structural strength and resistance to stress of the hull is derived primarily from the planking and its means of fastening.[4] Frame-based construction, on the other hand, relies on a complex structure of load-bearing elements that determine the shape and design of the hull, while the main function of the planking is to prevent water from entering the structure.[5]

It has yet to be determined precisely when this shift from shell-based to skeleton-first hull construction took place; most likely there was no universal point in time in the Mediterranean where all subsequently-built ships used only the skeleton-first method. Archaeological evidence, while limited, suggests that the transition was fairly gradual. The earliest known example of a strictly frame-based ship was found at Serçe Limanı, off the coast of Turkey. Dated to 1024/1025 C.E., this moderately sized ship (15.6 meters long with a capacity of 35 tons) demonstrates a pronounced departure from the shell-based construction method.[6] As far as can be discerned from the archaeological evidence, hull construction prior to the 11th century C.E. generally utilized mortise-and-tenon joints to fasten planks to one another. However, as will be seen by reviewing the

[2] Unger 1980, 21.
[3] Lane 1973, 119.
[4] Bellabarba 1996, 260.
[5] Ibid.
[6] Unger 1980, 104.

remains of various shipwrecks, there was a consistent pace of development in how this method was employed. This is perhaps best illustrated by comparing the shell-based construction of one of the very earliest examples of a ship built in this fashion, the early 14th century B.C.E. wreck at Uluburun, to one of the latest, the seventh-century C.E. Yassıada ship. While both ships were built with the same basic shell-based construction principles, it is clear that the latter was approaching the culmination of the effective usage of this method.

The two wrecks of pertinence at Yassıada date to the fourth and seventh centuries C.E., the latter yielding more information in regard to the study of ship construction. Both of these ships were built using the shell-based method, yet in the three centuries separating them it is evident that the reliance on mortise-and-tenon joinery for the structural integrity of the hull had decreased. Furthermore, the size and spacing of the joints in the planking of the fourth century ship, makes it clear that this process of transition was already well underway. When compared to the mortise-and-tenon joints in the hulls of earlier ships, such as the late fourth-century B.C.E. Kyrenia wreck, those in the fourth-century C.E. Yassıada ship were significantly smaller, more loosely fitted and more widely spaced.[7] Consequently, the interior structure of alternating floor and half-frame timbers and the four pairs of wales, the longitudinal timbers running along the exterior of the hull, served a greater role in strengthening the hull than in earlier vessels. These elements had yet to form an independently-sturdy framework, though, due to the fact that none of the framing pieces were attached to one another and the majority was not fastened to the keel, nor the stem- or stern-posts.[8] Nonetheless, the fourth-century Yassıada wreck represents an important step in the progression from shell-based to frame-based construction.

Of even greater importance to our understanding of the evolution of hull construction is the seventh-century Yassıada ship. Where the fourth-century ship's hull was fashioned

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[7] Steffy 1994, 79.
[8] Van Doorninck 1972, 138.

in the traditional Graeco-Roman method, with most of the planking having been erected before any framing elements were inserted, the seventh-century ship relied much more on the principles of the frame-based method. In this instance there was actually a mixture of both methods, though it is evident that frame-based construction was becoming dominant. Mortise-and-tenon joints were used to fasten the strakes of only the lowest portion of the hull, up to about the unladen waterline. However, these joints played a role in shaping and fitting just the first five or six planks on either side of the keel and even then their contribution to the strength of the hull was incidental.[9] Continuing the developments seen in the fourth-century Yassıada ship, mortise-and-tenon joints were even looser and further spaced and pegs were not utilized to fasten them in place.[10] The hull derived its principal strength from a structure of frames, placed early in the hull and set at relatively close intervals, and from four pairs of thick wales. Therefore, while the seventh-century Yassıada ship was not constructed strictly using the frame-based method, it is one the first archaeological examples where the principles of said method were applied so extensively. However, to the extent that it can be detected from the archaeological evidence, it would take over a century before shipbuilders were to abandon the core techniques of the shell-based method.

Several ships discovered at Dor (Tantura) lagoon on the Mediterranean coast of Israel may suggest an Arabic origin for frame-based construction. Dating from the fifth to ninth century C.E., the Tantura A, B, and F wrecks and the Dor 2001/1 wreck all demonstrate frame-based attributes. The earliest example, the Tantura A wreck, is a small vessel dated to between the fifth and the sixth century, with a length of 12 meters and a beam of four meters. Planking was nailed directly to the frames, which were themselves nailed to the keel, and there is no evidence of plank edge-joints. This pattern was repeated in the slightly larger (18-23 meters in length) Tantura B wreck, dated to the ninth century, and again in the Tantura F wreck (eighth century). Similarly, the Dor 2001/1 shipwreck also exhibits a lack of joinery between plank edge-joints. The frames

[9] Steffy 1982, 73.
[10] Ibid.

of this 16 meter long vessel were again nailed to the keel, with the planks fastened to the frames. It is evident that longitudinal reinforcement was derived by features such as the keel, false keel, central longitudinal timber, stringers, and wales, indicating a frame-based mindset in the construction process.[11] Thus, with the evidence provided by the shipwrecks at Dor lagoon it is apparent that the transition from shell-based to frame-based construction was taking place much earlier than previously supposed. At least along the coast of Israel, the fundamental techniques of shell-based construction had been all but abandoned in a few examples of moderately sized ships.

Though associated with the above-mentioned ships and of a similar size, the fifth to sixth-century Dor D shipwreck represents a construction method unlike that seen in those instances. Like the seventh-century Yassıada ship, planks were joined with loosely-fitted unpegged mortise-and-tenon joints.[12] Also, the interior of the planking carried scribe marks to assist in the placement of the frames. Thus the vessel was likely built predominantly shell-based, since the marks would have been unnecessary if frames were in place before planks.[13] Taken with the other wrecks at Dor, the juxtaposition of construction methods shows that the transition from shell- to frame-based ships could vary greatly even within a confined area and period.

This brings us to the next step in the development of Mediterranean shipbuilding, the ninth century Bozburun shipwreck. First brought to the attention of the Institute of Nautical Archaeology in 1973, this site was not formally excavated until 1995. In the intermediate years samples of amphorae were collected, establishing a preliminary date for the ship, while an extensive photographic record was created and general preparations were made for the ensuing excavation.[14] Dendrochronological analysis yielded a date of 874 C.E., indicating the latest year that the preserved oak timbers were

[11] Barkai 2007, 27-30.
[12] Harpster 2005b, 369.
[13] Ibid.
[14] Hocker 1995, 13.

cut.[15] The remnants of the Bozburun ship eventually yielded evidence vital to the understanding of the transition from shell-based to frame-based construction. Perhaps the most significant discovery was of the use of embedded dowels as a means of joining the edges of the ship's strakes. Though at first glance the presence of this method of plank joinery appeared to be just an alternative to the more common use of mortise-and-tenon joints, it was not until 2002 that the full implications of this discovery were realized.[16]

The dowels were utilized in a manner unparalleled in the Mediterranean thus far.[17] However, with the discovery of a number of 10th-century ships at Yenikapı in Istanbul it has been demonstrated that a similar construction method was utilized here. To properly illustrate the significance of the technique used in the Bozburun ship, the hypothesized construction process, at least as it is understood from the available evidence, must be described according to the study of these ship remains. Following the attachment of the stem and stern posts to the keel, the tail-frames, the midships floor timber and four other floor timbers (9, 1, E and I) were fastened to the keel.[18] At this point the third strake of planking on the port and starboard sides was fixed in place with treenails and nails; the garboard strake was left out until the vessel was nearly completed in order to aid in cleaning out the hull.[19] It was at this juncture, following the attachment of the third strakes that construction techniques took a distinct departure from earlier examples.

In the majority of instances where dowels were used to fasten plank edges there was also invariably some sort of cordage that was laced around the seam of the planks. This practice is known from a collection of Archaic Mediterranean shipwrecks ranging in date from the seventh to fifth centuries B.C.E.[20] The remains of the Bozburun wreck, on

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[15] Harpster 2005b, 7.
[16] Harpster 2005a, 89.
[17] Harpster 2005a, 91.
[18] Harpster 2005a, 92.
[19] Ibid.
[20] Harpster 2005a, 91.

the other hand, provide evidence that dowels were employed in a way closely paralleled by the use of mortise-and-tenon joints in the seventh-century Yassıada ship. In both of these cases, the fastening of the planking edges to one another had little to no effect on the structural integrity of the hull and served primarily to maintain the alignment of the strakes during the construction process.[21] But where the planking joints of the fourth-century Yassıada ship served the additional purpose of helping to define the method in which the hull was assembled, those of the Bozburun ship had only a temporary role. This is clearly supported by the fact that dowels were present only near amidships, both above and below the turn of the bilge.[22] The absence of dowels at both the bow and stern can be attributed to two reasons. For one, since they served only to align the planks, the dowels were unnecessary at the vessel's extremities because the structure of the standing frames was sufficient to allow for the fastening of the planks.[23] Additionally, the skill required to auger symmetrical dowel-holes from plank to plank far exceeded that necessary for cutting similarly arranged mortises.[24] The subtle and simple curvature of the strakes amidships meant that dowels were used only in the central sections.

The order in which planks were attached to the already erected frames of the Bozburun ship proceeded in a manner determined by the use of dowels.[25] Overall, this meant that after the third plank of strake three was attached to the midships frame and floor timbers 1 and E, it was necessary to then fix plank two of the fourth strake because it was easier to attach an outboard plank to an inboard one.[26] Planking was added in this way along the middle of the vessel until the bilge was reached. After nailing floor timber 5 to the keel, hull construction followed the general formula of attaching one or two new floor timbers then planking until reaching the eighth strake.[27] As already noted, this process

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[21] Harpster 2005a, 93.
[22] Ibid.
[23] Ibid.
[24] Ibid.
[25] Harpster 2005b, 430.
[26] Ibid.
[27] Harpster 2005a, 92.

was altered slightly when the shipwright planked the bow and stern. Instead of relying on dowels to keep planks in place, temporary clamps were used while the next plank was shored up and fastened to the frame and then nailed to the adjacent planks.[28] However, before planks without dowels were attached to those with them, the protruding ends of the existing dowels had to be sawn off. This procedure of simply nailing the planks to the frames and other planks was repeated throughout the remainder of the vessel, for by the later stages of construction there were enough frames and futtocks in place to obviate the need for dowels. Once all futtocks and top timbers were in place, the last strakes, the mast-step, shelf-clamps, and the galley bulkhead were all added and tar was applied to the interior of the hull.[29] Stringers were then added, along with ceiling planking and, one would assume, the deck beams, of which there were no remains.

For exactly how long the various iterations of the shell-based method remained in use in the Mediterranean, even in a vestigial sense as in the Bozburun ship, is wholly uncertain. Yet, it is clear that, owing to the discovery of the Serçe Limanı ship, by the beginning of the second millennium C.E. shipwrights preferred the frame-based method of ship construction for vessels of at least a moderate size. One key implication of the frame-based building technique used for the Serçe Limanı hull was that it necessitated some degree of forethought in the design of the hull. Confirming this supposition was the detection of consistent units of measurement throughout the hull that, because of their high frequency of use, were deemed as an intentional device of the shipwright. A base increment of 16 centimeters, which may have been a derivation of the Byzantine foot (31.23 centimeters) or some kind of convenient arbitrary length, was applied exactly in the scantlings of all timbers and the proportions of the hull.[30] Furthermore, units of four centimeters corresponded closely to multiples of the Byzantine finger, which equals one-sixteenth of the Byzantine foot.[31]

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[28] Harpster 2005b, 439.
[29] Harpster 2005a, 92.
[30] Steffy 2004, 154.
[31] Ibid.

While the construction sequence of the hull of the Serçe Limanı ship has been studied extensively and reproduced to a high degree of accuracy, the most important steps were taken in the earliest stages of the building process. The keel, composed of three timbers scarfed together, was laid first and was now, unlike in earlier vessels, one of the main sources of longitudinal strength in the hull. The stem- and two-piece sternpost were then attached to the upturned ends of the keel. Next, two floor timers, which would later form the only standing full frames in the hull, were shaped and their positions, equidistant fore and aft of the exact center of the keel, were marked.[32] Futtocks were then added to the midships frames, which were fashioned with one long and one short arm and set alternatively to port and starboard. As was generally the case with any frame-based ship, it was these two central frames that were pivotal in determining the shape of the hull. Consequently, they were likely designed with the aid of some form of geometric projection.[33] These frames were unlike those in a shell-based hull, which were shaped to directly fit the interior of the planking, even if the shape was obtained through the use of moulds.

Eight floor frames, four forward and four aft, were then added and were set with their long or short ends alternating from port to starboard like the two initial frames.[34] After all existing frames were fastened to the keel, which may have included one more pair of frames, five runs of planking were attached with nails.[35] The turn of the bilge, consistently the most difficult area of the hull to cover, was skipped and planking instead continued with the lowest side strakes. These runs of planking, fastened to the posts and midships floor timbers, defined the overall shape of the hull already established and determined by the frames.[36] The remaining frames and strakes were then added, after which the keelson, stringers and ceiling planking were attached. Aside from the side ceiling, clamps and deck beams, the remaining steps of the construction process and

[32] Steffy 2004, 155-165.
[33] Ibid..
[34] Pryor 1999, 62.
[35] Steffy 2004, 155-165.
[36] Pryor 1999, 62.

structure of the ship are unknown.[37] However, in the context of the evolution from shell-based to frame-based ship construction, the information provided by the Serçe Limanı wreck is certainly sufficient.

First and foremost, this wreck represents a pivotal transition in early medieval shipbuilding in the Mediterranean. While the frame-based method of construction was dominant in the building and design of the Serçe Limanı vessel, residual characteristics of the shell-based method were still present. This is most evident in the shaping and placement of the frames, in which only those amidships were predetermined.[38] One point that is important to keep in mind is that, with the few examples of vessels from this period that we do have, it is nearly impossible to estimate accurately the extent to which the frame-based method was practiced. There were certainly numerous other types of watercraft in use at this time and, depending on their size, shape and purpose, other construction methods were undoubtedly employed. However, at least for medium-sized cargo ships such as the one at Serçe Limanı, the frame-based method was the preferred means of construction and because of its many benefits over the shell-based method it is reasonable to assume that it eventually spread to most vessel types. In addition, it is also likely that several of the features of the frame-based method seen in the design of the Serçe Limanı wreck, such as the box-like shape of the hull and the rising and narrowing of the frames, were developed over the centuries following the Yassıada and Bozburun ships.[39]

As far as archaeological remains of sailing ships in the Mediterranean are concerned, the centuries immediately after the Serçe Limanı vessel look much like those preceding it. In the period of time separating the supposed widespread adoption of the frame-based method in the 11th century and the introduction of the square-rigged cog in the Mediterranean in the late 13th or early 14th century there are only ten examples of

[37] Steffy 2004, 155-165.
[38] Pryor 1999, 62.
[39] Steffy 1994, 91.

significance to this study. The most noteworthy of these ships were the two discovered in 1898 at Rovigo, in Italy's Po Delta.[40] These well-preserved vessels, named the Contarina ships, were uncovered and, considering the inability to preserve the remains at the time, modern scholars should be very thankful for the relatively sophisticated and extensive excavation and recording techniques used. Owing to its better preservation at the time of discovery, the first and oldest ship has received the most attention and therefore will be covered more thoroughly here.

The Contarina I ship was an average sized two-masted lateen-rigged ship dating to the early 14th century, likely about 1300.[41] Those parts that remained included almost the entire bottom of the hull, the starboard side to above the turn of the bilge, the port side up to below the bulwarks and half of the stem and sternpost, while the keelson, two mast steps, and lower stringers were in their original positions.[42] The ship was of moderate dimensions, with an overall length of around 21 meters, a keel of 16.5 meters in length and a maximum breadth of 5.2 meters.[43] These measurements accord well with contemporary ships of this type, though it was a little smaller than the standard size, as described by Doge Pietro Ziani in 1229 and the treatise *Fabrica di galere* of the 15th century.[44] Constructed almost entirely of oak, the Contarina I ship is thought to have been built exclusively with the frame-based method.

The shape of the hull was defined by three frames amidships and sections near the stem and stern posts, all of which were nailed or spiked to a keelson and a two-part keel.[45] Ribbands were then attached to the control frames in order to determine the shape of the rest of the frames. There were 28 frames towards the bow and 29 towards the stern, and each frame was composed of five pieces.[46] External wales and internal stringers were

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[40] Pryor 1999, 62.
[41] Bonino 1978, 13.
[42] Steffy 1994, 91.
[43] Steffy 1994, 93.
[44] Bonino 1978, 15.
[45] Pryor 1999, 63.
[46] Ibid.

fastened along the hull at two levels, where the floor timbers were fastened to the first futtocks and where the first futtocks were fastened to the top-timbers. In terms of the development of medieval shipbuilding techniques, the placement of the wales and stringers is of particular interest due to the apparent use of certain conventions found in later Venetian treatises. For instance, the distance from the surface of the ceiling planking to the second wale corresponds exactly with the breadth of the main section given in later Venetian shipbuilding treatises.[47] The relationship between these two quantities underscores the importance of the second wale as a key line in the shape of the Contarina hull as well as the use of elements of the *partison* method.

It is reasonable to postulate then, that at the beginning of the 14th century and likely earlier, wales were in the process of replacing previously used thin strakes in order to control the shape of the frames after the setting up of the principal sections of the hull.[48] Moreover, the presence of such techniques at this time reflects the idea that shipbuilders were following a theoretical approach to the methods described in the 15th century treatises, lending credence to the scenario that said methods were already a part of the shipbuilder's vernacular well before they were formally put to paper.

A contemporary of the Contarina I vessel, the Culip VI ship was a small coasting vessel. Discovered in 1987 off the northeastern coast of Spain, it is believed that this vessel was built in the Mediterranean, due to the practice of joining the futtocks to the floor timbers by means of hook scarfs.[49] The date of 1300 was determined from the array of ceramic evidence found, composed of the cargo from Granada and the crew's wares from Languedoc.[50] Eric Reith and his colleagues were responsible for the reconstruction of the Culip VI ship, and he used the measurement of the flat midships and the distance between the mast-step and what was most likely the bow as the basis for his work.[51]

[47] Bonino 1978, 15.
[48] Ibid.
[49] Hocker et al. 2006, 7.
[50] Ibid.
[51] Castro et al. 2008, 8.

Taking the dimensions and proportions of the Contarina I vessel for comparison, Reith gave the ship an overall length of 16.35 meters, a beam of 4.11 meters and a depth of hold of 2.06 meters.[52]

Of special significance were the numerous markings and Roman numerals found on Contarina I's surviving floor timbers. The floors were separated into two categories, the first consisting of timbers 114 to 138 and the second timbers 113 to 104.[53] The floor timbers in both groups were numbered consecutively with Roman numerals and had markings at their centers and near the turn of the bilge, though timbers 139 to 141 possessed neither numbers nor marks. These three timbers were further distinguished by the unique way in which they were fastened to the keel and the planking.[54] Using the Roman numerals and markings as a guide during reconstruction, it was determined that timbers 113 and 114 were main frames, while 138 was one of the tail frames. The three unmarked frames, numbers 139 to 141, would have been set beyond that tail frame, likely by the use of battens during the construction process. It was established that the other frames, however, were designed prior to construction with the use of some type of geometric calculating device.[55] This may have been a figure similar to the *mezzaluna*, or half-moon, described in later shipbuilding treatises, which was used to predetermine the necessary incremental alterations that were made to the frames to achieve the desired hull shape.

One of the latest substantial archaeological examples of a medieval vessel built in the frame-based fashion was uncovered in 1958 near Ferrara, Italy and is named the Logonovo boat.[56] This vessel is dated to the early 15th century, thus making it roughly contemporary with the compilation of the treaty of Michael of Rhodes.[57] It is thought to

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52 Castro et al. 2008, 8.
53 Hocker et al. 2006, 8.
54 Ibid.
55 Ibid.
56 Steffy 1994, 93.
57 Bonino 1978, 15.

have been a two-masted *barca* with lateen sails and fairly modest dimensions, having an overall length of 10 meters, with the keel measuring 8.65 meters, and a maximum breadth of 2.55 meters.[58] The Logonovo boat was probably built in the frame-based fashion, with the shape of the hull being defined by the main section and ribbands. Likely due to its comparatively small size there was no real keel, only a central strake, nor a keelson, though the foremast was stepped atop a heavy timber that was incorporated into the stem post.[59] The frames were assembled in a fashion similar to those in the Contarina I ship, though treenails were used at the joints instead of bolts.[60] Longitudinal reinforcement was achieved by the use of footwales on the bottom of the hull. Upper stringers were not present but may have been part of the original construction.[61]

Aside from its archaeological value as an example of medieval Mediterranean shipbuilding, the Logonovo boat does not contribute any overly innovative or original information. Yet, it does represent a continuation of several of the techniques used in the construction of the Contarina I ship, though obviously on a smaller scale. In addition to the abovementioned similarity in frame assembly, the location of the raked foremast and the symmetry of the bow and stern are notable features seen in both the Contarina I ship and the Logonovo boat.[62] Perhaps of most importance is the fact that it was equipped with a lateen rig well after the introduction of the square-rigged *cocca*, emphasizing the preference for the more easily-manned lateen sails on small craft in the Adriatic.[63]

The last ship to be examined in this brief survey of medieval shipwrecks is the Contarina II ship, dating to some 150 years after the first. While discovered in a far more advanced

[58] Steffy 1994, 93.
[59] Ibid.
[60] Ibid.
[61] Bonino 1978, 17.
[62] Ibid.
[63] Ibid.

state of deterioration than its earlier counterpart, the Contarina II vessel did provide precious structural evidence missing from the 14th century wreck.[64] This included significant portions of the bulwarks and upper structure, but unfortunately no original wood from the wreck survives today. Despite the lack of remains for modern researchers to study, a fairly accurate model of the vessel and photographs taken during the excavation have permitted a satisfactory reconstruction of the original ship.[65] The mid 16th century date of the wreck was derived from pottery recovered from the site, albeit with some difficulty owing to the long period of use of the type of pottery found.

Even with a century and a half separating the construction of the two Contarina ships, there are several similarities in their design and assembly. Both were built with the frame-based method, with the shape of the hull most likely being defined by the midship frame(s) and the tail frames at the bow and the stern. The framing timbers of both ships were also fastened to one another with iron bolts. These similarities cease, however, with the arrangement of the cross-beams in the Contarina II ship. Yet, since theses timbers were not preserved on the Contarina I ship, one cannot comment definitively on whether or not they would have been constructed in the same way on both ships. Nevertheless, the way in which the cross-beams were set on the Contarina II ship is certainly notable.

Much like ships of Roman times, the hull of the Contarina II vessel had protruding cross-beams, each one in this case being set in the space between ordinary cross-beams attached to every third futtock.[66] The protruding beam was fixed to both the stringer and the wale by means of swallow-tailed (or dove-tailed) mortises, but it was not fastened to the frame in any way.[67] The presence of the protruding cross-beams is somewhat peculiar in the case of the Contarina II vessel due to the fact that they are most often associated with shell-based construction. With this method of construction the beams

[64] Bonino 1978, 19.
[65] Ibid.
[66] Bonino 1978, 20.
[67] Ibid.

were used to retain the shape and the consistency of the hulls lines prior to the insertion of the frames and the memory of this practice is evident in the shipbuilder's choice to leave the protruding beams and the futtocks unattached.[68] While it may at first be unclear why such a seemingly anachronistic feature would have been in place on a skeleton-built vessel of the 16th century, these beams would have probably contributed to the reinforcement of the hull On the other hand, with the limited number of excavated medieval shipwrecks and the extent of deterioration of such wrecks in the Mediterranean, in which only the lowermost portion of the hull is typically preserved, it may be premature to postulate that protruding cross-beams were not common.[69] In fact, there is a great deal of 14th through 16th-century iconographic evidence from central and northern Italy that does depict protruding cross-beams on lateen-rigged vessels and even on some ships with square sails.

One conclusion that is certainly apparent from the aforementioned collection of shipwrecks is that it is somewhat limited in scope. This was a necessary convention for a few reasons, the primary one being that the reconstruction of an early 15th century Venetian round ship does not necessitate the detailed description of every known wreck from the end of the Roman period to late-medieval times. Furthermore, a great number of these wrecks remain known only in the most limited sense, with little or no excavation or publication undertaken since their discovery. In regards to the study of ship remains exclusively, only 30 of the over 100 shipwreck sites from this period preserve fragments of the ship's hull, while just 14 have been researched and published.[70] Adding to this skewed representation of medieval shipbuilding is the noticeable clustering of Mediterranean shipwrecks dated to the early medieval period. There is a clear lack of shipwrecks from after the seventh century, with an almost complete absence of any seafaring evidence in the eighth and ninth centuries.[71]

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[68] Bonino 1978, 21.
[69] Bass 1972, 71.
[70] Harpster 2005b, 356.
[71] Harpster 2005b, 357.

Viewed from a purely archaeological context this occurrence would be difficult to account for. Yet, when combined with historical documentation, the reasons for such trends are more easily accounted for. Events such as the seventh-century arrival of Muslim seafarers in the western Mediterranean and pandemics that may have killed a substantial portion of the European population likely contributed to the decline of seaborne activity by disrupting normal commercial practices.[72] As important as the historical record is to an understanding of seafaring, though, not addressing it in a thorough manner does not detract from an ability to understand the narrower subject of ship construction.

Hull Design and the Frame-based Method

In describing the adoption and practice of the frame-based method of hull construction, another topic of distinct importance to the discussion of shipbuilding in the medieval Mediterranean, particularly in Venice. It has been postulated that concurrent with the implementation of the principles of frame-based construction must have been the spread of the Venetian method of design later explained in several Venetian shipbuilding treatises.[73] Known as the *partison* method, this involved the process of defining the shape of the hull by means of geometrical aids.[74] The method was essentially defined by a set of rules that delineated certain measurements for the principal parts of a ship. Specifically, these included the longitudinal section of the hull (the keel, stem and stern), the mainframe and the three-dimensional shape of the hull.[75] The *partison* method was more broadly based on two general concepts. The first is the tripartite division of the midships floor timber, while the second is a series of proportions applying to the measurement of the bottom of the hull at midships.[76] These design components would have further necessitated some kind of standardized length in order to be consistent and

[72] Harpster 2005b, 357.
[73] Bellabarba 1996, 261.
[74] Bellabarba 1993, 274.
[75] Bellabarba 1993, 276.
[76] Harpster 2005b, 493.

repeatable. Without going into much greater detail, as this topic will be covered extensively in the reconstruction of the *nave quadra*, it is essential to note that this method, or some variation of it, was in use well before it was first mentioned in shipbuilding treatises.

Of the distinctively Venetian *partison* method itself, the earliest known historical mention comes from a letter sent from the Brindisi shipyard to the court of Charles I of Anjou in the year 1275.[77] This document is perhaps best known in the subject of maritime history because of the description it contains of a particular kind of galley. But it is of special value in this context because of the terminology that is used in explaining the construction of such a galley, the majority of which is unique to the *partison* method.[78] While it is uncertain whether or not shipwrights at Brindisi actually followed the *partison* method in the design of their galleys, the fact that the letter was an affirmative reply to the specific orders of Charles' court implies that they did in fact follow said guidelines. Nevertheless, the letter does affirm the important point that, well before the industrial operation of the Venetian Arsenal in its heyday, the construction of a type of vessel in two separate places could be achieved through the use of a common list of dimensions.[79]

The Contarina I vessel described earlier exhibits the first archaeological evidence from Venice itself of the use of the *partison* method, if only in a limited sense. As alluded to, certain aspects of the hull demonstrated an understanding of the construction techniques explained in later Venetian treatises. In addition to evidence that the arrangement of the main and tail frames was predetermined is the idea that the second wale was instrumental in determining the shape of the rest of the frames.[80] The use of various proportions of the Venetian foot was also discovered in the measurements for the length of the keel, the breadth of the hull and the height of the second wale over the first

[77] Bellabarba 1996, 259.
[78] Ibid.
[79] Hocker et al. 2006, 7.
[80] Hocker et al. 2006, 9.

strake.[81] This last aspect reflects a further reference to the methods used in the Venetian manuscripts in that the second wale was located three Venetian feet above the bottom planking. This distance, referred to as *trepie*, was a vital reference measurement used repeatedly in the *partison* method.[82]

Maybe the best proof for the direct use of the design and construction techniques used in later Venetian manuscripts is the Culip VI ship. The remains of this vessel retained evidence of a system of numbering and marking the floor timbers to aid in the construction process. It is known from later documents, particularly an early 17th-century manuscript of João Baptista Lavanha, that such a system was indicative of the calculations made during the design of a vessel in order to shape the frames between midships and the bow and stern.[83] With this in mind, Eric Reith sought to experimentally apply the methods described in the Venetian manuscripts to the remains of the Culip VI ship to see how closely the two would correlate.

With just the floor timbers remaining, though, he was only able to establish the narrowing and rising of the frames. The latter refers to the gradual increase in the distance between the bottom of the floor timber and the top of the keel, moving outwards from midships to the bow and stern.[84] Narrowing, on the other hand, is the gradual reducing of the width of the floor timbers up to the tail frames.[85] Reith calculated these modifications and measured the totals in comparison to the remaining floor timbers from 114 to 138. Overall, the projected measurements corresponded very closely with those from the actual wreck, though with a few caveats. Namely, that while the estimated narrowing could be applied to the entire group of floor timbers, the rising agreed only with timbers 127 to 138.[86] Yet, this is not entirely irregular, as there are instances in the

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[81] Harpster 2005b, 494.
[82] Ibid.
[83] Hocker et al. 2006, 8.
[84] Bellabarba 1993, 278.
[85] Bellabarba 1993, 279.
[86] Hocker et al. 2006, 8.

Venetian manuscripts where the rising of the floor timbers is not always taken into account directly before or after the mainframe.

Looking back before the beginning of the 14th century for instances of the direct use of the techniques seen in later shipbuilding treatises is somewhat more ambiguous than the evidence already seen in the Contarina I and Culip VI ships. However, it is still evident that early medieval shipwrights in the Mediterranean were using some method of predetermination in the design and construction of ships. This is apparent in both of the vessels from Bozburun and Serçe Limanı, though any system of design used in these examples obviously indicates a developmental step below that seen in the Contarina I and Culip VI ships. A consistent feature of the remains of these two ships is the presence of a standard unit of measurement, representing a fundamental component in the development of any kind of design system.[87] In the Bozburun ship this unit measured 34.5 centimeters in length and it and various multiples of it were responsible in dictating the shape and location of vital elements of the hull's structure.[88] This included the eight principal framing timbers, as well as the flat section of the center of the hull and the length of the keel, which was a multiple of the floor width. This trend is further seen in the placement of the mainframe, which then enabled the locations of the other primary floor timbers to be determined, based again on the 34.5 centimeter unit.

It can be argued that these occurrences are coincidental. Yet, when the construction process is taken into consideration, the argument for the use of a clear design system based on a standard unit of measurement is certainly more convincing. The sequence of assembling the key frames, which is reflected by the consecutive use of proportional measurements based on the standard unit and the breadth at midships, was essential to the construction of the rest of the ship.[89] For instance, none of the bottom strakes could be attached without first setting up the primary framing timbers. But as clear as it may

[87] Harpster 2005b, 486.
[88] Harpster 2005b, 487.
[89] Ibid.

be that the Bozburun ship was based on some set of design instructions, the larger question of whether all or the majority of ships of this period employed the use such guidelines requires other parallels outside of this isolated example. Fortunately, the Serçe Limanı vessel aptly serves this role, providing a close corollary for the techniques seen in the Bozburun ship.

The Serçe Limanı vessel, like that found at Bozburun, also utilized a standard unit of measurement, which was evident in the scantlings of the majority of the timbers and the proportions of the hull.[90] This increment measured about 16 centimeters (actually 15.8 centimeters, but rounded to 16 to simplify reconstruction) and was so prevalent in the structural components of the hull that it and its multiples were adopted as the basis for the scale used in the research of the ship.[91] As was the case in the Bozburun vessel, the standard unit dictated the shape and placement of the mainframe, which, also like the mainframe of the Bozburun ship, was divided into three sections.[92] Furthermore, the length of the central flat section of the mainframe in both vessels was ten units, though this amount was reached through different proportions.[93] In the Serçe Limanı ship the bottom of the mainframe and the lowermost portion of the sides lacked any curvature, so both could be characterized as more or less straight lines.[94] These were then joined by a constant angle throughout most of the hull for the turn of the bilge, so that creating the frame shapes was a fairly uncomplicated task.

The tripartite construction of the mainframe in both vessels is an important design feature in establishing the progress of construction methods up to the Venetian manuscripts. Although the shape of the hulls of both the Bozburun and Serçe Limanı vessels was fairly straightforward, with only subtle rising and narrowing of the frames towards the extremities, there is a noticeable improvement in the design and function of

[90] Steffy 1994, 85.
[91] Steffy 2004, 154.
[92] Harpster 2005b, 490.
[93] Ibid.
[94] Steffy 1994, 87.

the midships frame from the late ninth to the early 11th century. In the Bozburun ship the deadrise of the hull is evident in all three sections of the midships floor timber. In the Serçe Limanı vessel, on the other hand, this characteristic is seen only in the end sections of the midships floor timber, which utilizes a considerably shorter center section than that in the Bozburun vessel. This rather minor change is significant in that it is a necessary alteration to allow for the adaptation of the mainframe to the growing complexity of early medieval hulls.[95] With increasing emphasis on the narrowing and rising of the frames to achieve more advanced hull shapes, the midships floor timber of the Bozburun vessel is quite restrictive. However, this frame in the Serçe Limanı and later ships is far better suited to determining the shaping of the hull, in which the center section and the two end sections could be altered independently to account for narrowing and rising respectively.

The similarities in construction exhibited by the Bozburun and Serçe Limanı vessels continue in the placement of the principal hull timbers. The midships frame in both ships was placed at the center of the keel and before any other frames. After this, the primary frames were set up using similar proportions and multiples of their respective standard units. In some cases, however, corresponding frames in both vessels were attached in reversed positions, where a primary frame in the Serçe Limanı hull would be forward of the mainframe and its counterpart in the Bozburun hull would be aft.[96] This trend can also be seen in the positions of the tail frames. While the locations of these timbers was determined based on the same multiples of the center flat length of the mainframe for both ships, the way in which these multiples were applied was again reversed. Therefore the distance from midships to the stem on the Serçe Limanı vessel is proportionately equal to the distance from midships to the sternpost on the Bozburun vessel and vice-versa.[97]

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[95] Harpster 2005b, 497.
[96] Harpster 2005b, 490.
[97] Harpster 2005b, 491.

Despite these slight variations in the construction sequence for individual components of each hull's structure, the overall similarities between two vessels constructed almost a century and a half apart and in different regions are very compelling. Consequently, several implications can be reached about the state of ship construction and, more to the point, design in the early medieval Mediterranean. For one, it is clear that shipwrights were well into the process of developing the framework for the conceptual method of shipbuilding that would eventually be incorporated into the Venetian treatises.[98] That this framework was characterized by two very similar sets of standards for the construction of the Bozburun and Serçe Limanı vessels suggests that these guidelines were easily transferable over both time and distance.[99] They also must have been at least moderately successful, which may reflect the adaptability and the resulting ease of repetition of the system.

The use of proportional measurements is a feature integral to the utility of the design system employed in the Bozburun and Serçe Limanı vessels and a major component on which the construction techniques of the Venetian manuscripts is based. Fundamental in the use of proportions is the shaping of the vessel at midships, as witnessed in both of the above mentioned vessels and the shipbuilding treatises. In tracing the development of medieval ship design, this is perhaps the most significant parallel between the archaeological and written (e.g. shipbuilding manuscripts) evidence.[100] The emphasis on the precision necessary for shaping the mainframe is reflected in the prominence with which this process is covered in the Italian manuscripts. Due to the importance of this structural feature in the overall design of the hull, it is usually addressed in a thorough manner and often accompanied by detailed illustrations in the treatises.[101] In the sequence of construction evident in the Bozburun and Serçe Limanı vessels, it is clear that shipwrights were already aware of at least some of the core principals of later shipbuilding methods.

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[98] Hocker et al. 2006, 7.
[99] Harpster 2005b, 493.
[100] Harpster 2005b, 496.
[101] Ibid.

Searching for instances of the use a design method in ship construction before the ninth century is far less fruitful than for the period after this point and inevitably leads into the question of where and how this process originated. In asking this question it is generally assumed that the development of the *partison* method, or any similar design technique, was closely associated with the adoption of the frame-based method of construction.[102] This well-documented occurrence in northern Europe and Scandinavia in the 15th century is usually cited as an historical precedent for this notion.[103] However, it is difficult and somewhat misguided to assume that this kind of parallel can be applied to Byzantine-era ships in the Mediterranean, if for no better reason than the marked discrepancy in historical resources. While there is a relative abundance of documentary evidence, such as the Venetian treatises, for the roughly 375 years following the Serçe Limanı wreck, there is no such material for the period before.[104] Thus the archaeological evidence, though more plentiful from the fourth to 11th century, is unable to benefit from the complementary information provided by later shipbuilding manuscripts.

Despite the simultaneous implementation of frame-based construction and the *partison* method, or a similar design scheme, in late 15th and early 16th-century shipyards on the Atlantic seaboard, it is possible that the same does not hold true for the pre-9th –century Mediterranean. It is reasonable to believe that some kind of design method was developed and employed before the 11th century, when at least the archaeological evidence suggests that some ships were built exclusively frame-based.[105] An important aspect of this issue is the use of mixed shipbuilding methods, particularly the utilization of pre-fabricated moulds. This practice presents a number of implications, both in terms of design and construction. From the design perspective, moulds can be responsible for determining the shape of the hull by initially determining the shape of one or more

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[102] Bellabarba 1996, 262.
[103] Ibid.
[104] Harpster 2005b, 498.
[105] Bellabarba 1996, 262.

frames.[106] The mould(s) would be placed in the hull and then removed after the side strakes are formed to it, after which the frames are inserted with no trace of the moulds.[107] In this instance, construction of the hull would proceed in accordance with the shell-based method since the mould(s) would act only as a guide to the shipwright and planking would still occur before framing. The use of temporary battens should also be noted in this regard. Like the moulds, these dictated the shape of the hull and determined the shape of the majority of frames, serving the same fundamental role as the side strakes in the shell-based method.[108]

Archaeological evidence for the use of moulds in the Mediterranean is fairly sparse, but the two Imperial Roman barges of Lake Nemi and the Punic ship of Marsala provide some of the most compelling evidence for this practice.[109] In the case of the former examples it is each barge's surprising level of consistency in the angle of the turn of the bilge for the mainframe and the rest of the hull that has led to the conclusion that some kind of mould must have been used. This trend is repeated in both vessels with only minor discrepancies, in spite of the fact that there is a noticeable contrast in their hull shapes. The same characteristics are evident in the Marsala ship. However, unlike the very flat bottoms of the Nemi ships, the floor of the Marsala ship exhibits distinct narrowing and rising, making the case that much stronger that a mould must have been utilized to reproduce the more complicated frame shapes throughout the ship.

Drawing on evidence from the practices of Greek shipwrights from the 16th to the 18th century and up to the present, Kostas Damianidis has classified six categories for the application of geometry (often with the use of moulds) in shipbuilding. Beginning with the technique he describes as "master frame and ribbands", he lists the categories chronologically and highlights their main features in relation to the evolution from one method to the next. Of special interest are the parallels between the Greek methods

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[106] Basch 1972, 35.
[107] Ibid.
[108] Basch 1972, 37.
[109] Bellabarba 1996, 262-264.

Damianidis describes and those used in other parts of the Mediterranean. The "moulding with adjustable templates" technique is of particular interest. Like the *partison* method, it employs geometric aids (three to five) to determine the shape of the moulds for the hull.[110] Furthermore, these aids were often assisted with a *metzarola* diagram, much like the *mezzaluna* described in Italian shipbuilding treatises. Since it has been hypothesized that similar aids were used in Greek architecture of the Classical period, the idea that elements of the *partison* method originated in Classical Greece appears to be a reasonable one.[111] Such a supposition, if it were to be supported by archaeological evidence, would contribute greatly to the shell-based/frame-based discussion. In addition, it would bring into question the theory that ship design was congruent with the adoption of frame-based construction.

In the Lake Nemi and Marsala ships there is surely some kind of predetermination at play in the forming and reproduction of the mainframe. And while it is likely that moulds were used to achieve this outcome, there are also interesting questions raised about the role of design in the construction of these vessels. A shipwright could certainly use moulds without involving the more complex techniques of the *partison* method, for instance, but even then the progression to such a method of design was theoretically not that far off. Sergio Bellabarba proposed a sequence of steps using a half-mould whereby this scenario could have easily arisen. Placing the half-mould against the turn of the bilge outwards from the mainframe, from which the half-mould is taken, one would make note of the position of the center point of the keel on the mould at each consecutive framing station. When the extremities of the hull are reached there would then be a graduated scale of markings indicating the necessary narrowing of the floor timbers.

Using a device similar to the *mezzaluna* of the Venetian treatises to calculate the rising with the scale recorded in the half-mould would then allow the prefabrication of floor

[110] Damianidis 1998, 223.
[111] Damianidis 1998, 232.

timbers to be placed in the shells of other ships.[112] The essential point here and in searching for the origins of design methods in Mediterranean ship construction is that it is not when shipwrights learned to predetermine frame shapes that is of the greatest importance. Obviously moulds could facilitate this task, while still maintaining the methodology of the shell-based construction technique. Rather the question should be when did predetermined frame shapes replace the role of the planking in dictating the form of the hull?[113]

[112] Bellabarba 1996, 264.
[113] Steffy 1994, 84.

CHAPTER III
THE TRANSITION FROM SHELL-BASED TO FRAME-BASED CONSTRUCTION

One topic that is certainly unavoidable and indeed integral to any discussion of the maritime archaeology of the Mediterranean is the debate over the transition from the shell-based to frame-based method. And while the archaeological evidence discovered in the Mediterranean has certainly played a pivotal role, the scope of the discussion is considerably more far-reaching. In fact, the first hypothesis to be reached about this subject was based on the shipbuilding practices of Scandinavia and other northern European countries, as most of the Mediterranean wrecks discussed in the previous chapter had yet to be discovered.

Yet, with the uncovering of the remains of several ships off the coast of Turkey, such as the Uluburun, Kyrenia, Yassıada, Bozburun and Serçe Limanı vessels, and now the large number of vessels found at Yenikapı, the initially straightforward conclusions about the shell-based/frame-based debate have been significantly revised in order to account for this new evidence. Instead of distinguishing such vessels strictly on the basis of their method of construction, as either shell-based or frame-based exclusively, a more complicated and descriptive approach to classification was taken. A principal component of this has been the redefinition of the time span involved in the shift from one method to the other in order to include transitional techniques, which often involved the mixing of both methods in the same ship. A corollary to this development has been the desire to emphasize the understanding of the nature and reasons for the transition from shell-based to frame-based construction, as opposed to simply seeking to arbitrarily assign these classifications to specific vessels.

The Shell-based to Frame-based Debate

In the past the shell-based versus frame-based debate, both within and outside of the Mediterranean, has been oversimplified and devoid of the nuances suggested by the archaeological evidence. The limited number of medieval shipwreck remains in the Mediterranean was partly responsible for the belief that the transition from shell-based to frame-based was a unilinear occurrence. This idea was first espoused in the 1940s by James Hornell, whose work encompassed research on water transportation of all kinds from around the world.[114] Of particular interest were his conclusions on the structural principles of all kinds of hulls, especially the distinction between the clinker-built vessels of Scandinavia and the carvel-built vessels of the rest of Europe. Hornell emphasized the difference between these two modes of construction by identifying and describing principles such as the sequence of assembly and the edge-to-edge or overlapping arrangement of the planks.[115]

As observant as he was about these distinctions, though, Hornell made some conceptual missteps when addressing the transition from shell-based to frame-based construction. Despite common practice in Scandinavian shipyards, he characterized this shift as purely the preconceived result of the inventive shipwright.[116] Furthermore, he dismissed the idea of a gradual evolution from one technique to the other or the amalgamation of both into the same hull as highly implausible.[117] Hornell reached these conclusions without the vital information that we now possess, namely the data provided by wrecks later found off the Turkish coast and elsewhere. His conclusions were extensively scrutinized in the decades to come. At the forefront of this repudiation was the Scandinavian ethnographer Olof Hasslöf, who sought to widen the application of the clinker/carvel distinction into a more universal designation of watercraft as either possessing a

[114] Bellabarba 1996, 261.
[115] Hocker et al. 2004, 5.
[116] Hornell 1946, 194.
[117] Ibid.

"watertight shell" or a "waterproofed frame."[118] This terminology, with its basis in the sequence of construction of a ship's hull, eventually transformed into the shell-based and frame-based distinction generally used in the description of all types of vessels.

One key element of the argument waged against Hornell's thesis was Hasslöf's observation of construction methods in use in the shipyards of northern Europe. In particular, he presented evidence of the use of ribbands, which are thin longitudinal timbers attached to the main and tail frames in order to guide the shape and erection of the remaining frames and achieve the desired lines of a hull.[119] One corollary to this practice, also pointed out by Hasslöf, was the somewhat cruder procedure in which the main frames were initially set up and then followed by the shaping and assembly of the later frames by the shipwright's eye.[120] Hasslöf's description of these additional methods of hull construction proved to be instructive in many regards. Perhaps of most importance was the idea that there was not always a universally clear distinction between the ways in which a hull was assembled. The awareness of this now incontrovertible fact was pivotal in developing the debate over the adoption of the frame-based technique in the Mediterranean.

Discoveries from shipwrecks found along the coast of Turkey that dated to the medieval period made it necessary to rethink Hasslöf's conclusions about medieval ship construction. One of the most prominent figures to take up this task with insight and depth was Lucien Basch. While building on the criticisms of Hornell's conclusions initially posed by Hasslöf, Basch introduced a wholly new perspective on the subject. Instead of focusing exclusively on the sequence of construction, he sought to delineate the role of a hull's framing components and their function in the overall structure of the vessel.[121] Basch did this by describing frames as either "passive" or "active," depending on whether they were used with the shell-based or frame-based technique

[118] Hocker et al. 2004, 6.
[119] Bellabarba 1996, 261.
[120] Ibid.
[121] Hocker et al. 2004, 6.

respectively.[122] In other words, he stressed the importance of the planking or the framing in determining the shape of the hull as a means of classifying construction methodology. According to his view, in the shell-based system the form of the planking determines that of the framing, thus giving the frames a "passive" role.[123] Conversely, in the frame-based system the arrangement of the framing structure dictate the shape of the outer planking, thereby giving the frames an "active" role.[124]

Concerning the overall development of hull construction techniques, Basch proposed the idea that the frame-based method was most likely adopted only after the use and improvement of a series of intermediary methods. As demonstrated in the preceding chapter, this theory is clearly borne out by the archaeological evidence. Beginning with the fourth-century Yassıada ship, it is apparent that shipbuilders were departing from the strict shell-based construction methodology seen in earlier shipwrecks, namely the late fourth-century B.C.E. Kyrenia ship.[125] The zenith of the mortise-and-tenon system of edge joinery may have been achieved around the time of this vessel, or maybe more so with the first-century B.C.E. Madrague de Giens ship, and thereafter the shift to frame-based building effectively started.

The construction of the fourth-century Yassıada ship suggests that the structural integrity previously provided by the system of mortise-and-tenon joinery was being phased out and that greater emphasis was being assigned to structural components like frames, keelsons and ceiling and deck structures.[126] However, other indications of the frame-based methodology were also evident. Most noteworthy was the role played by the first half-frames placed in the hull. These timbers seem to have been inserted at midships after the first five strakes were assembled and in this capacity they were greatly responsible for the definition of the transverse shape of the hull, making the fourth-

122 Basch 1972, 16.
123 Ibid.
124 Ibid.
125 Pryor 1999, 65.
126 Steffy 1994, 84.

century Yassıada ship one of the earliest known instances of this practice.[127] A similar, but less conclusive, mixing of construction processes is evident in the late second or early third century C.E. Bourse de Marseille shipwreck. The remains of this wreck exhibit an alternation between shell-based and frame-based techniques, in which it is possible that some frames may have played an active role in the forming of a limited number of strakes.[128] Such framing elements could have been inserted after several of the bottom strakes were erected according to shell-based principles, as seen in the fourth-century Yassıada ship. However, because only three frames could be characterized in this way, it seems that the construction of the Bourse de Marseille ship was predominantly achieved by shell-based means.[129]

These developments were seen to an even greater degree in the seventh-century Yassıada ship, where the planking joints were used more as a means of guiding the shape of the hull than lending any real strength to it, especially since the tenons were spaced very far apart and were no longer pegged.[130] However, the arrangement of the planking joints still dictated the ship's method of assembly.[131] With the ninth-century Bozburun ship, though, the pace of the transition from shell-based to frame-based construction increased at a rate previously undocumented in the archaeological evidence. Demonstrating what was, for all intents and purposes, a complete departure from the principles of shell-based construction, the Bozburun ship is the first real example of frame-based methods, both in design and construction, being embraced to a considerable extent. This vessel still employed the use of edge joinery by means of embedded dowels, but they served only to align the planks during the construction process. Thus, the Bozburun ship plainly demonstrates that, contrary to what Hornell first posited, the shift from assembly methods that utilized embedded edge joinery to those that did not

[127] Harpster 2005b, 501.
[128] Pomey 2004, 31.
[129] Ibid.
[130] Pryor 1999, 65.
[131] Harpster 2005a, 93.

was in no way a sudden occurrence.[132] With the evidence provided by the seventh-century Yassıada ship, the ninth-century Bozburun ship, and the eleventh-century Serçe Limanı ship, it is more accurate to claim that there was instead a gradual abandonment of the principals of the shell-based method parallel to the slow adoption of the techniques used in the frame-based method. Yet, the numerous shipwrecks at Dor Lagoon discussed earlier further complicate the largely accepted unilinear mode of evolution from shell- to frame-based vessels.

The near culmination of this transition, as shown by the archaeological evidence, is exhibited by the eleventh century Serçe Limanı vessel. Being completely devoid of any method of joining plank edges to each other, this ship has been described as the first archaeological example of frame-based shipbuilding methods. However, this vessel still possesses remnants of the shell-based methodology. While the 12 floor timbers and frames that were erected before any strakes were attached to the hull did essentially determine its shape, the bottom strakes that were subsequently laid also contributed to shaping the hull.[133] The remaining frames could only be added after this point.

Those aspects of the mixed shell-based and frame-based construction seen in the examples just cited led to the call for general redefining of the shell-based/frame-based debate. The simple division between shell-based and frame-based, based primarily on the understanding of a ship's construction sequence, is no longer acceptable. Instead, a more conceptual approach is now embraced (originally proposed by Patrice Pomey in 1988), which seeks to address the three principal themes of design, assembly sequence and structural philosophy.[134] Integral to this framework of thought is the replacement of the terms shell-based and frame-based with the more appropriate description of construction methods as either shell-based or frame-based.[135]

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[132] Harpster 2005a, 93.
[133] Pryor 1999, 65.
[134] Hocker et al. 2004, 6.
[135] Ibid.

First enumerated by Patrice Pomey in 1988, the idea of a structural philosophy behind the conception and assembling of a vessel has received growing attention and has contributed greatly to this discussion. In this context, the principles of construction are clearly differentiated from the methods of construction, the latter of which has clearly dominated the interpretation of ship remains in the past.[136] By looking at shipwrecks as more than isolated archaeological examples in terms of their construction alone, exploring the factors prior to building has expanded the debate appreciably. This includes taking into account the initial purpose of the vessel, stressing the importance of the function and usage of the ship, as well as the shipwrights own experience in the process.[137] Also, before construction can begin, the shipwright must reconcile the two concepts at play at this preliminary stage, those being form and structure. The structural concept is inevitably responsible for the final form of the vessel, though it can vary greatly depending on the method of achieving the intended shape of the ship.

In regards to ancient shipbuilding, the shortcomings of the conceptual approach, which is largely theoretical in this context, are readily apparent. It is nearly impossible to know (in most cases) either the concept of form or structure, as perceived by the shipwright. In addition, without the techniques of design and construction adopted after the 11th century C.E., the ancient shipbuilder may not have had the need or motivation to separate concepts of form and structure and thus the two would have been indistinguishable and arisen simultaneously during the construction process.[138] With these aspects being indiscernible in most of the early archaeological evidence, the importance of the method of construction remains vital to the attempt to understand the symbolic factors behind a ship's intellectual conception. Yet, this approach can also lead to overgeneralization, as in the simple shell-based/frame-based division. Indications of the process of construction are not always evident, such as the use of certain moulds or ribbands and the traces of temporary nailing, so instances of mixed

[136] Pomey 2004, 26.
[137] Ibid.
[138] Pomey 2004, 27.

construction methods may be overlooked in favor of making a shell-based or frame-based identification.[139]

Returning to the debate over the transition from shell-based to frame-based, one of the more beneficial developments in this discussion has been the altering of these classifications to account for both the conceptual and construction aspects. In essence, it is more accurate to look at the way in which the shape of the hull was accomplished, be that from either a longitudinal or transverse perspective.[140] In the shell-based method the shipwright basically builds the vessel from the outside inwards, assembling the planking of the hull before any framing is secured in the interior of the hull. Thus the hull shape is achieved in a predominantly longitudinal manner by the planking, which runs parallel to the keel.[141] As a result, one can look at a shell-built vessel as placing greater emphasis on the shape of the hull than on the internal space, which was necessarily limited by this building technique.[142] One the other hand, as is sharply contrasted in the Serçe Limanı vessel, the frame-based method allowed the interior space of the hull to take precedence over the exterior shape.

Since a number of the frames were erected before any planking and assembled perpendicularly to the keel in a series of transverse shapes, it can be said that hulls built with frame-based methods were conceived in a predominantly transverse manner.[143] Though such descriptions are fairly similar to the shell-based/frame-based division, they do a significantly better job at incorporating the conceptual aspects discussed earlier. Furthermore, they reflect not only a shift in construction techniques but a far more important shift in the shipwright's mentality towards utilizing those techniques towards a given result. Thus the present discussion inevitably begs a number of questions pertaining to the reasons for this transition.

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[139] Pomey 2004, 28.
[140] Steffy 1995, 419.
[141] Ibid.
[142] Harpster 2005b, 506.
[143] Ibid.

Why the Change to Frame-based Construction?

Comprehensively exploring the myriad possible political, social and economic explanations for the transition from shell-based to frame-based construction in the Mediterranean is certainly not the intention here. However, neglecting to discuss such a fundamental change in maritime history would represent a significant omission. Furthermore, as demonstrated by the shell-based/frame-based debate, this topic is also prone to overgeneralization. On the scale of the myriad of individual shipyards that existed throughout the Mediterranean it is of course impossible to know all of the reasons why a shipwright would so drastically change his method of construction. However, while there were certainly a great number of factors to account for this transition, there are several basic hypotheses that can be touched upon.

There are several issues to consider regarding the shipyard and shipwright in the early medieval Mediterranean world. The first is the idea of a demand for change exacted by outside agents that would compel the shift to frame-based construction. Implicit in this is the notion that current methods were perceived to be a failure, though this does not seem supportable by the simple fact that the shell-based technique persisted for so long.[144] Change likely came from many quarters and in some cases was likely motivated by the perceived limitations in the shell-based method, especially in contrast to the multiple advantages of the frame-based method.

In terms of the amount of labor and the number of workers, the discrepancy between the two techniques is obvious. Building something like the Kyrenia ship, with its many closely-fitted mortise-and-tenon joints, required several highly skilled workers, which was increasingly less sustainable during the late Roman period.[145] During the construction of the replica of this vessel, for instance, shipwrights found that it consumed labor at a rate of between five and ten times that required for a frame-based

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[144] Harpster 2005b, 507.
[145] Unger 1980, 105.

vessel.[146] Since in most cases ship owners were independent businessmen with limited assets, they were unable to compensate for the decline in slavery, hence the necessity for more cost-effective building techniques became imperative.[147] Whereas in the construction of a frame-based vessel the shaping of the keel, posts and frames were the only steps that required exceptional skill and craftsmanship, pretty much the entire building process for a shell-built vessel necessitated such workers.[148] The sculpting of the planks too was very labor intensive and was very wasteful of wood.[149] For a frame-based vessel the addition of planking was a fairly simple affair, with the frames providing a guide for their shape, and thus could be performed by carpenters with less knowledge and experience.[150]

Either factors like labor and cost were not as pressing of concerns up until the Byzantine era as they were in later times or, more likely, builders were unaware of more efficient methods of construction.[151] As a consequence, early shipwrights perfected and honed the skills required to produce as efficient and sophisticated hulls as they were capable of at the time. As demonstrated by the archaeological evidence, these hulls were in no way inferior in terms of the level of craftsmanship they required. Yet what prevented the next great technical progression was the apparent inability to execute the geometric skills necessary to predetermine hull shapes in a frame-based, transverse fashion. It should be noted, though, that there was some level of planning in the conception of a shell-based hull. However, early shipwrights envisaged these forms from a predominantly longitudinal perspective. Thus they sought to carefully control the longitudinal shape of the strakes, albeit most often by eye, while the desired transverse curvatures were achieved as a result of, and probably also with the use of offsets.[152]

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[146] Throckmorton 1987, 92.
[147] Steffy 1994, 85.
[148] Unger 1980, 105..
[149] Steffy 1994, 84.
[150] Unger 1980, 105.
[151] Steffy 1994, 84..
[152] Steffy 1994, 85.

One of the most pronounced characteristics of the shape of the Serçe Limanı hull is its distinctly box-like shape, itself an innovation made possible by the construction techniques of the frame-based method. As is evident from the reconstruction of this vessel, the initial assembly and form of the frames allowed a far more acute angle for the turn of the bilge than in earlier ships. This resulted in an appreciable increase in cargo capacity and usable space by means of both dimensions of length and beam.[153] The question is, to what internal or external factors can this new emphasis on utility be attributed? One explanation points to the commercial influence of the new Muslim Empire and the cultural shift that may have taken place throughout most of the Mediterranean following its advent.[154] With wealth and power in Muslim society being based heavily on trade and commerce, the influx of Arab merchants into the principal port cities could have caused fundamental changes to the structure of these pursuits. No longer did the economy rely on a foundation of slave labor, but a new free market-type system in which the transit of goods over water was an appealing way to accrue wealth, while also proving both profitable and reliable.[155] The development of more economically efficient methods of building ships and carrying materials, then, would have been a natural result of this new environment.

One other interesting hypothesis about the Arab influence on shipbuilding practices concerns the conflict that developed between the Muslim and Byzantine cultures and its affect on the consumption of timber.[156] It postulates that with the rivalry between the ever growing raiding fleets of the Arabs and the Byzantine Navy, ship construction grew so quickly as to lead to mass deforestation of the lands around the Mediterranean.[157] Whether or not this theory is completely accurate is a legitimate question, but it does offer an interesting explanation for the transition in ship construction methods. It has also been proposed that the Muslim-Byzantine conflict forced both sides to increase

[153] Pryor 1999, 66.
[154] Harpster 2005b, 508.
[155] Throckmorton 1987, 94.
[156] Kreutz 1976, 106.
[157] Ibid.

production of ships, which required the widespread adoption of quicker and more efficient construction techniques.[158] It seems reasonable to consider this scenario as at least contributing to the eventual implementation of the frame-based technique.

[158] Kreutz 1976, 106.

CHAPTER IV
MEDIEVAL NAUTICAL INNOVATIONS IN THE MEDITERRANEAN

The principal purpose of this chapter will be to provide an intermediary step in the nautical history of the Mediterranean between the archaeological evidence of the early middle ages and the reconstruction of the *nave quadra* of the 15th-century manuscript of Michael of Rhodes (identified hereafter as MRMS). There are two aspects described here, both of which supply a necessary preface to the reconstruction. The first is the development of ship types from just before the beginning of the 14th century to around the start of the 16th century. The main facet is the introduction of the northern European *cog* to the Mediterranean, an event which had a profound effect on the seafaring history of the Italian maritime republics. The possible explanations and motivations for this transition will be favored over the detailed description of certain vessels, as this will feature more prominently in the reconstruction of the *nave quadra*. Integral to this overall discussion is the wider phenomenon known as the Nautical Revolution of the Middle Ages, so described by the Venetian scholar and nautical historian Frederic C. Lane. This refers generally to the changes around 1300 C.E. in the methods of navigation and in the construction, rigging and armament of sailing ships.[159]

The second topic of importance in this chapter is the development of written culture, particularly in Venice. The main focus of this chapter will be the collection of shipbuilding and nautically themed manuscripts written between the 14th and 17th centuries. While the 1434 manuscript of Michael of Rhodes will be the primary concern of the subsequent chapter, it will receive a brief explanation here in order to be able to compare it with the contents of other manuscripts. The practice of writing down instructions for the construction of ships and the recording of other maritime information

[159] Lane 1973, 119.

represents a significant step in the progress of nautical history in Venice, and this chapter will seek to explore the motivations and implications of this occurrence.

New Ship Types and the Nautical Revolution of the Middle Ages

Before coming to the pivotal introduction of the northern European square-rigged, sternpost-ruddered cog in the Mediterranean, it is necessary to discuss the body of contractual evidence for the crusader ships of King Louis IX of France (b. 1214/d.1270and also known as St. Louis).[160] The importance of these documents is derived from many factors; first and foremost that they preserve the earliest surviving detailed dimensions for sailing ships in the Mediterranean.[161] In addition, the extensive information they possess has permitted a fairly thorough reconstruction of the ships mentioned while also providing vital details about the general characteristics of round ships around 1300. The contracts record agreements made between St Louis and the maritime republics of Marseilles, Genoa and Venice for the lease and purchase of ships for his two crusades of 1248 to 1254 and 1270.[162] Various types of ships are described in the contracts, which include dimensions for oared vessels, both *galeae* and *taridae*, and sailing ships, referred to as *naves* and *salandria*.[163]

In the evolution of Mediterranean sailing ships, those of St. Louis represent the culmination of pre cog-type vessels.[164] While it is believed that there were more similarities than differences between the characteristics of early Medieval cargo ships and those of the middle ages, the crusader ships seem to have been exceptional.[165] The most significant difference between these ships and others was their size. The largest was the Venetian *navis Roccafortis*, which was said to have three decks and a carrying

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160 English 2005, 455.
161 Pryor 1999, 63.
162 Ibid..
163 Pryor 1984, 171.
164 Pryor 1999, 63.
165 Unger 1980, 123.

capacity of 806 metric tons, compared to 323 metric tons for the two-decked ship.[166] The three-decked vessels could carry up to 100 horses, crusaders and their attendants, in addition to as many as 1,000 pilgrims on a typical voyage.[167] While most documentary evidence deals with the three-decked ships, some vessels had two, and sometimes four, and all could have additional half-decks or gangways on the bulwarks on either side of the main deck.[168] As these vessels were designed to function in a military context, they had large castles at both bow and stern, enabling soldiers to attack their enemies from an elevated position.[169] Overall, the crusader ships were deep-drafted and beamy, with a length-to-breadth ratio from 3:1 to 4:1 and a beam-to-depth ratio of around 1:1.45 for the *Roccafortis*.[170]

The ships of St. Louis were rigged in the typical fashion for round ships of the middle ages, that is with lateen sails. While the largest had three masts, the majority had just two, both of which were stepped in the keelson. As on a galley, the mainmast was longer and slightly raked forward and was generally equal in size to the length on deck of the vessel.[171] The lateen sails were of massive proportions and thus required yards that were around 30 percent longer than the ship and composed of two spars, woolded together.[172] The mizzenmast was also longer than the ship, though smaller than the mainmast. Auxiliary sails particular to various weather conditions were carried on board, four of which were used on the mainmast and three which could be changed out on the mizzenmast.[173] As one would expect, management of the yards and sails necessitated a large crew, at a rate of about one crewman per 10 tons of carrying capacity, plus servants and ship's boys.[174]

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[166] Pryor 1999, 64..
[167] Unger 1980, 123.
[168] Pryor 1999, 63.
[169] Lane 1934, 36.
[170] Pryor 1984, 185.
[171] Unger 1980, 125.
[172] Ibid.
[173] Lane 1934, 36.
[174] Pryor 1999, 63.

In the 13th century all round ships in the Mediterranean were steered by means of two heavy side rudders located at the stern. Movement of the rudders was guided by a combination of tackles and tillers, which enabled them to be turned on their axes and raised or lowered vertically.[175] These ships were further characterized by their curved end posts and fairly pronounced round hulls, which when combined with a substantial superstructure, produced a distinctive appearance. As far as the features of their construction are concerned, they had relatively light scantlings and thus a more liberal use of frames and beams compared to northern vessels of the same era.[176] This is evident in the remains of the Contarina I ship. In order to support the light framework of the hull and lend further longitudinal support, round ships needed substantial external reinforcement, and so heavy wales were placed evenly up to the gunwale. These had corresponding stringers on the interior of the hull. Through-beams also lent structural strength, while further supporting the decks and protecting the hull.[177] At the stern these transverse beams likely provided mounting points for the steering oars. Such a timber, of substantial dimensions, was discovered among the remains of the Contarina I ship, and was in the appropriate position to have served this role.[178]

After undergoing only slight modifications for more than two centuries, the Mediterranean round ship would become completely revolutionized around the beginning of the 14th century. In fact, the typical two-masted lateen-rigged ship would not so much be revolutionized as replaced by a Mediterranean version of the *cog* of northern Europe. A relatively high-sided bulk carrier, the cog had been developed progressively by shipwrights of northern Europe from the 11th through 13th centuries.[179] It was characterized by a very flat bottom and sharp turn of the bilge, with end-posts that were also raked at a sharp angle to the keel. The distinct profile was softened over time to improve sailing ability, while a heavy keelson was added amidships to support the

[175] Pryor 1984, 282.
[176] Unger 1980, 126.
[177] Pryor 1984, 181.
[178] Ibid.
[179] Unger 1980, 138.

mast. Overall, though, the *cog* seems to have retained its key structural features, including a length-to-breadth ratio of around 3:1, a high freeboard and posts that rose higher than the bulwarks, with the stem post being the highest.[180]

What made the *cog* so influential in the Mediterranean, though, was its use of both a square rig and a rudder attached to the sternpost.[181] The square sail, especially, presented many distinct advantages over the complicated lateen rig, particularly in terms of labor savings. Due to the fact that a lateen sail was cut so that it was necessary to always have the same corner to windward, tacking involved swinging the massive yard all the way around the mast.[182] This was not only a dangerous task in inclement weather but it also required a large crew to complete. On the other hand, a square rig, like that on the *cog*, had the ability to turn either edge to windward, the forward edge of which would then be held taut with a bowline. The square sail was also equipped with reef points and a bonnet, the former of which were used to shorten sail, while the latter could increase the sail's area.[183]

The other great innovative contribution of the *cog* to Mediterranean ship design was the stern-mounted rudder. There is, however, some debate as to the technical superiority of this arrangement over the traditional two side-rudders.[184] For instance, on Venetian galleys, which had curved sternposts, two extra rudders were still carried in addition to the stern-mounted one, long after the adoption of the stern rudder in the Mediterranean. Yet, with the straight sternpost of the *cog* this was unnecessary and it seems that the stern-mounted rudder was easier to use as it eventually became predominant on all round ships. Despite the misgivings of some over the supremacy of the stern-mounted rudder, this device demonstrated several advantages over the quarter-rudder design. For one, the attachment of the rudder with pintles and gudgeons along the length of the sternpost

[180] Unger 1980, 138.
[181] Lane 1973, 122.
[182] Ibid.
[183] Ibid.
[184] Ibid.

greatly lessened the likelihood of losing the rudder in heavy seas.[185] It was also better protected from damage during naval battle, either by collision with another ship or tampering by enemy combatants. Lastly, the stern-mounted rudder would have allowed for better control of the ship, due to its forward-raked bottom. Even with these advantages, though, the stern-mounted rudder was not widely accepted in the Mediterranean until the 14th century, long after it was likely first introduced in this region.[186]

When the *cog* was first introduced to Mediterranean seafarers is a point of some contention. Traditionally, this occurrence is attributed to the year 1304 C.E., as documented by the Florentine chronicler Giovanni Villani.[187] He recorded that in this year Biscayan, or Basque, pirates sailed *cogs* into the Mediterranean and that local shipwrights were so impressed with the design that they began copying the new type of ship.[188] It is generally accepted now, though, that the date of 1304 is almost certainly too late. For one, Mediterranean shipbuilders were undoubtedly exposed to northern vessels as early as the beginning of the First Crusade in 1095 and the increased number of pilgrims and ships in successive campaigns would have made this even more likely.[189] Furthermore, the majority of these ships frequented ports all along the Mediterranean coastline on their way to the Holy Land, thus giving their features a high level of exposure. Yet, for reasons as yet unclear, these designs were not incorporated into the Mediterranean shipwright's vernacular until around 1300.

What may have contributed to the adoption of the *cog* were both the changes in the technology of navigation and the changes in the shipping market.[190] The mariner's compass was integral to the new navigational methods of the medieval Mediterranean,

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[185] Mott 1996, 108.
[186] Mott 1996, 134.
[187] Friel 1994, 78.
[188] Ibid.
[189] Unger 1980, 129; Bellabarba 1999, 83.
[190] Unger 1980, 183.

particularly the practice of dead reckoning. This method utilized elementary arithmetic and geometry to estimate distances and directions from one port to another. This information was then accumulated and recorded in special port books, known as *portolans* in Italy, one of which was compiled for the entire Mediterranean around 1250.[191] The next step was the creation of the *portolan* chart, a type of marine chart derived from the information contained in the port books. The earliest of these dates to about 1270 and is the earliest map found to have been drawn to scale with strict mathematical methods to accurately depict landforms, with the distance and directions between them.[192] The map is called the *carta Pisana*, indicating it likely came from Pisa, and is the only surviving example from the 13th century.

Contemporary with the first navigational charts was a new type of compass that allowed the direction of a ship to be determined within nearly five degrees, thus distinguishing 64 points of the compass.[193] Maintaining a straight course was also accomplished by the use of a traverse table, referred to as the *tavola di marteloio*, which enabled a navigator to plot a more direct route.[194] Together with the compass and the *portolan* chart, the traverse table drastically increased the conditions under which one could sail effectively. No longer was the navigation of a ship dependent on clear weather. With the use of dead reckoning the position of a ship could be determined accurately no matter the weather and therefore sailing during the winter months was now acceptable. This change was noticeable almost immediately, as the Great Council of Venice extended the sailing season by one to two months as early as the 1290s.[195]

Despite all of the apparent advantages of the *cog* over the two-masted lateeners, it was still a matter of decades before the former gained dominance in the Mediterranean.[196] In

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[191] Lane 1973, 119.
[192] Lane 1973, 120.
[193] Ibid.
[194] Ibid.
[195] Ibid.
[196] Lane 1973, 123.

Venice it was not until 1315 that the *cog* was first mentioned, though Genoese records indicate references to *coche*, as the *cog* would come to be known, as early as 1302.[197] There are additional and somewhat ambiguous mentions of Genoese *coche* in the 12th and 13th centuries, but the degree to which these resembled the vessels mentioned by Villani is unknown.[198] Yet the term *cocha* would not become the general designation for large round ships until after the middle of the 14th century. There is also some uncertainty about whether or not the term *cocha* was particular to the single-masted square-rigged *cog*-type vessel.[199] There is pictorial evidence, such as the Pizzigani chart, that suggest that some of these vessels were equipped with a square mainsail and a lateen sail on the mizzenmast, like the *nave quadra* of the MRMS.[200] One factor that may have contributed to the greater use of *coche* around this time was the Black Death plague of 1348.[201] Due to major shortages in labor and the significant upward spike in the demand for industrial goods, the relatively smaller crew requirements and higher capacity potential of the *cocha* would have made it an even more attractive alternative to the two-masted lateener.[202]

Though slightly beyond the scope of this study, the role of the *cocha* in the development of the fully-rigged ship is an important topic worth addressing here. From a modern perspective, the evolution of Mediterranean, specifically Italian, ship types after the beginning of the 14th century does not appear as linear and clear as one would prefer. This is attributable mostly to a general confusion concerning the terminology for certain ship types. For instance, the term *cocha* itself did not always describe a square-rigged *cog*-type, single-masted vessel with lapstrake planking. Some have suggested that this word should not be used for the exclusive designation of rigging arrangement, but for the kind of structural characteristics and construction methods used in a vessel.[203] Thus

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[197] Friel 1994, 78.
[198] Ciciliot 1999, 192.
[199] Lane 1973, 123.
[200] Ibid; Bellabarba 1999, 88.
[201] Friel 1994, 78.
[202] Unger 1980, 184.
[203] Bellabarba 1999, 85.

cocha would indicate a vessel built in the traditions of northern Europe, with features such as a flat bottom, frames attached with iron rivets and edged sections for instance, though constructed with the frame-based technique. As a result, those vessels constructed in the Mediterranean with the methods of that region would have been known by a different name.[204] This argument certainly has some abstract value and this is perceptible in the iconographic evidence. The earliest depictions of the *cocha*, for example, show a two-masted vessel with a square mainsail and lateen mizzen.[205] It would seem then, that the term *cocha* was not necessarily synonymous with *cog* in the strictest sense, though this may have initially been the case, but more a general term for a round ship equipped with a square mainsail.[206]

It can be implied from its adoption and spread throughout the Italian maritime centers, that the *cocha* exhibited advantages over the *cog*, on which it was based, and the earlier lateen-rigged *nave*. To a great degree, the *cocha* shared many of the attributes of the *cog*; namely its square rig, stern-mounted rudder, capacious hull form, and perhaps its flat bottom.[207] These features made the *cocha* a proficient bulk carrier with relatively low operational costs, which would have certainly added to its appeal among merchants. In Genoa such vessels could have two and even three decks, with a typical capacity of about 500 tons, making them significantly larger than *cogs*.[208] Though initially equipped with one mast like the Northern *cog*, the *cocha* utilized two, with the combination of a square mainmast and a lateen mizzenmast. Combined with the benefits of the stern-mounted rudder and the other advantages just described, this new rigging arrangement made the *cocha* the most technologically advanced medieval sailing vessel in the Mediterranean.

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[204] Bellabarba 1999, 85.
[205] Friel 1994, 79.
[206] Bellabarba 1999, 86.
[207] Friel 1994, 78.
[208] Ciciliot 1999, 192.

However, the above case is further confused by the slightly later appearance of another medieval ship type, the *carrack*. The origins of this term are far from certain, but most attest to a13th century Arabic source, where the word *karaque* indicated a small vessel.[209] The first appearance of this term may even date to as early as the ninth century, in which this type of vessel was used exclusively on rivers.[210] Whether or not *karaque* had any relationship to the later usage of *carrack* is unknown, but the associated argument for its origin in the Spanish language is compelling given that fact that there was considerable Arabic influence on the Iberian Peninsula in the Middle Ages.[211] On the other hand, this assertion is suspect in light of the preference in Spain for these ships to be referred to as *naves*. Whatever the source for the word *carrack*, the eventual use of the term to refer to two and three-masted medieval vessels is the more pertinent point to consider. In English, the *carrack* was a definite ship type, denoting the largest of vessels both in northern Europe and the Mediterranean, but documents from around 1350 indicate that it was applied only to Genoese vessels at this time.[212]

Pictorial evidence for *carracks* from the 15th century suggests many general features that distinguished this type of ship from others. Most obvious is the change in the arrangement of the rigging, which typically consisted of three masts, the fore and main being square-rigged and the mizzen carrying a lateen. Though it is clear that the size of the mainsail was increased appreciably, this change and the increase in the number of sails likely had little effect on speed, but were instead meant to improve overall sailing quality.[213] Tacking into the wind would have been made easier by the small foresail, while the lateen mizzen would have helped in beating to windward. The appearance of the *carrack's* profile was characterized by a prominent forecastle, which may have been used to throw Greek fire on Arabic ships, sitting atop an upward curving stem, with a

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[209] Friel 1994, 79.
[210] Bellabarba 1999, 86.
[211] Friel 1994, 79.
[212] Ibid.
[213] Lane 1934, 42.

noticeably shorter aftercastle.[214] The single stern-mounted rudder and deep hull with relatively high freeboard and a flat bottom amidships were retained from the design of the *cog*, though the presence of two or three decks was a newer development.

As far as the size and capacity of these ships is concerned, it is not surprising that there was a general increase in both due primarily to the marked increase in trade between northern Europe and the Mediterranean. The Venetian Timbotta Manuscript of c1445 specifies a range of dimensions for vessels between about 125 and 625 tons, though it is unclear whether or not these pertained solely to *carracks* per se.[215] In general, one can discern a division in the keel-to-beam ratio between ships below and above 400 tons capacity, with those above being progressively wider and those below equally narrower. The largest of these ships was around 42.7 meters in length from stem post to sternpost, with a floor width for the flat bottom of around 3.8 meters.[216] Though there were certainly exceptions to these dimensions based on regional variations, they do provide a good idea of the size of ships in the 15th-century Mediterranean.

The invention of the full-rigged ship can be seen as the next step of the natural progression of ship design from the *cog* to the *cocha* and *carrack*. Though it is unclear where this type of ship was first utilized, credit is most often attributed to Basque shipbuilders of the Bay of Biscay.[217] Even if it did not specifically derive from this area, it is generally accepted that the full-rigged ship was developed somewhere along the Atlantic coast of Europe, as it was adopted most quickly here because it was so well suited to the sea conditions between northern and southern Europe.[218] Essentially all of the structural and design features demonstrated by the *carrack* and discussed earlier were evident in the full-rigged ship, though on a larger scale. The most profound change was, of course, the addition of multiple sails. This involved not only the use of up to

[214] Friel 1994, 79.
[215] Friel 1994, 81.
[216] Ibid.
[217] Unger 1980, 216.
[218] Ibid.

four masts, but the replacement of the large square mainsail with multiple smaller sails. There was also the phasing out of the large lateen sail on the foremast in favor of the use of all square sails on three masts, the earliest evidence for which dates to between 1420 and 1436.[219] By the end of the 16th century Venetian round ships could be equipped with up to 10 sails, with two square sails hung from the bowsprit, three square sails on both the foremast and the mainmast and a lateen sail on each of the two mizzenmasts.[220] However, the second mizzenmast, or bonaventure mast, did cease to be used after about 1550.

Shipbuilding Treatises of Medieval Venice

The small collection of 15th and 16th-century Venetian shipbuilding treatises is arguably the most relevant evidence to the study of medieval ship construction practices in the Mediterranean currently available. This is especially the case given the paucity of archaeological evidence for seafaring during this revolutionary period in southern European maritime history. Granted there are the contractual documents for the crusader ships of St. Louis already discussed, but these lack the essential detail concerning the conceptual foundation of design that is so vital to an understanding of ship construction methodology. However, the value of these records in the development of the notion that design ideas should be communicated by means of writing should not be underestimated.[221] Furthermore, they reflect the roots of one of the main purposes of the shipbuilding treatises, that being the preservation of successful designs for later reproduction by means of government regulation.[222]

The question that naturally arises here is what finally compelled shipwrights to record their ship designs and construction methods. Surely the spread of literacy was a factor, but these treatises are not intended for a general audience of the 15th century. They were

219 Friel 1994, 80.
220 Lane 1934, 45.
221 Dotson 1994, 161.
222 Ibid.

meant to be consumed and understood by individuals experienced in shipbuilding and other maritime matters, given the fact that the texts make general assumptions about the knowledge of the reader on these topics.[223] However, the earliest manuscripts were little more than personal notebooks, a *zibaldone*, containing practical seafaring information and compiled by seamen who worked in various capacities on Venetian vessels.[224] These texts were not necessarily intended as shipbuilding manuals like later examples, but were instead meant to present an array of nautical topics, which happened to include data on the construction of a variety of contemporary vessels.

The earliest known example of a maritime *zibaldone* in which shipbuilding is described in relatively extensive detail was conceived in 1434 by Michalli da Ruodo, or Michael of Rhodes as he is more commonly known.[225] However, even this manuscript was copied from existing documents, as is evident in the sections on sail making and shipbuilding. There are arguments that would seem to indicate Michael was the original author of these parts, such as the resemblance between their arrangement and that of the rest of the text.[226] Yet, several factors point to the greater likelihood that it was copied, like the absence of any corrections, missing illustrations and the scattering of the shipbuilding materials throughout the text.[227] Moreover, nowhere does Michael imply that he had any experience as a shipwright, yet most of the information he provides would have easily been accrued during his 40 years of service on the galleys of the Venetian Navy and the merchant fleet.[228] The documentation of this service forms a significant part of the content of the treatise, in addition to information on mathematics, navigation and ways to calculate time.

[223] Dotson 1994, 162.
[224] Hocker et al. 2006, 3.
[225] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_writing.html (2008, 7 July)
[226] McManamon 2001, 24.
[227] Ibid.
[228] Hocker et al. 2006, 10.

About 10 years after the MRMS was composed, between 1444 and 1449, Zorzi Trombetta of Modon created his own *zibaldone*.[229] Being that Zorzi was a trumpeter, as his name reflects, on Venetian ships from 1446 to 1449, it is not surprising that his book begins as a compendium of musical entries, initially entered by two different scribes.[230] The rest of the text is a mix of topics of personal interest, including materials on mathematics and medicine, but the most pertinent parts here pertain to seafaring. The information on shipbuilding and sail making resembles that found in Michael's and other manuscripts, though there are differences in the mathematical dimensions for some vessels as well as some curious editorial changes in certain details. For example, there are several instances where mathematical problems were copied without actually working them out, as the right result is achieved but in the wrong way. An interest in matters related to problems of strategic and military engineering is another fairly prominent feature of Zorzi's text, while the notes made at sea about his dealings in wine provide a unique perspective compared to the other treatises.[231]

The next treatise, entitled *Ragioni antique spettanti all'arte del mare et fabriche de vasselli*, was commissioned by an anonymous source and recorded in 1470 by as many as eight different scribes, one of which was the actual patron.[232] This individual was most likely a member of the De Milliis family of Venice, as the text was in their possession by at least 1499, which accords well with their involvement in both the maritime business and naval defense of Venice.[233] The contents once again represent a collection of various subjects relating to seafaring, with an emphasis on business and naval affairs at sea. Contemporary trends in navigation techniques are described in some detail, much of which was lifted from other sources, including those as early as the 14th-century *Zibaldone da Canal* manuscript. The portions on ship construction contain several errors which had to be corrected, possibly demonstrating some difficulty in

[229] Hocker et al. 2006, 4.
[230] McManamon 2001, 21.
[231] Hocker et al. 2006, 4.
[232] McManamon 2001, 19.
[233] Ibid.

understanding the original source, but overall the descriptions of Venetian vessels are fairly lucid. There is also evidence that it was frequently updated by the owner, who kept a record of the successful designs of specific shipwrights of prominence in the Arsenal, and even put down his own design of the master frame for a great galley.[234]

As the MRMS was copied from earlier documents, so too did it influence later nautical treatises. Until 2004 it was believed that one of Michael's younger contemporaries, a Pietro di Versi, was responsible for compiling the R*axion de' Marineri*, or Method for Mariners, out of excerpts from Michael's manuscript.[235] However, upon closer observation it was discovered that Michael's name was simply scratched out and replaced by Pietro di Versi's sometime after it was copied by Michael from 1443 to 1445. The most historically significant iteration of the material contained in the MRMS was one of three copies made just after 1500, when the manuscript seems to have come into the possession of Giovanni Battista Ramusio (b.1485; d.1557) , the secretary to the Venetian Senate and then the Council of Ten, editor of classical texts and collector of an expansive compendium of travel accounts.[236] It was copied by Ramusio himself and, after making its way to Florence, later became known as the *Fabrica di galere*. Yet, since it deals with the construction of more than just galleys and additionally discusses various other maritime topics, the actual manuscript title of *Libro di marineria*, or A Handbook of Seafaring, is probably more appropriate.[237]

The second and third copies, the *Arte de far vascelli* (The Art of Making Vessels) and the *Trattato dell'arte di fabbricar navi* (Treatise on the Art of Shipbuilding), along with the *Fabrica di galere*, are more focused overall on shipbuilding than the MRMS.[238] The three copies further differ from Michael's text in a few fundamental ways. For one, it would seem that the fact that three different copies were created suggests that they were

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[234] Hocker et al. 2006, 4.
[235] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_writing.html (2008, 7 July)
[236] Hocker et al. 2006, 4.
[237] Ibid.
[238] Hocker et al. 2006, 5.

intended to be circulated as shipbuilding manuals, as opposed to the more personal nature of Michael's text. These may have been utilized in the Venetian Arsenal by those in administrative positions, such as the "admiral," to assist in their duties of outfitting vessels.[239] As being representative of the fairly prominent craft of shipbuilding in medieval Venice, the manuscripts could have also served as preparatory guidelines for apprentice shipwrights in the Arsenal.[240] Yet, the act of copying and disseminating the information contained in the manuscripts may also point to the basic desire for those with the means to do so to simply be in possession of knowledge.

There is a noticeable difference in the nature of the documentary evidence from the 15th century, the manuscripts of Michael of Rhodes, Zorzi of Modon and the De Milliis family, and the treatises of the 16th century and later. All three *zibaldone*, particularly the first two, reflect the personal and eclectic interests of individuals who had nautical backgrounds and thus a vested concern in sharing this information for the benefit of the Venetian maritime industry and indeed themselves. These treatises were the property of private collectors and existed as unique expressions of a growing interest in the elevation of the social worth of the craft of shipbuilding.[241] They also mirrored greater trends developing in the overall written culture of the merchant sphere of Venice. The 14th-century *Zibaldone da Canal* is an ideal example of this, being a kind of written instrument to assist in the commercial endeavors of individual businessmen.[242] These manuals were collected over a long span of time from a variety of sources, testifying to the educational development of the Venetian mercantile elite.[243] A concern for practical matters was featured above all, including an interest in the conversion of weights, measures and moneys into Venetian quantities, the business conditions of various markets and information about taxes and fees.[244] The manuscripts of Michael of

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239 McManamon 2001, 18.
240 McManamon 2001, 25.
241 Ibid.
242 Hocker et al. 2006, 10.
243 Dotson 1994, 11.
244 Dotson 1994, 12.

Rhodes, Zorzi of Modon and the De Milliis family can be seen as examples of the progression from the merchant handbook to the shipbuilding treatise of the 16th century.

With the composition, by around 1520, of the *Fabrica di galere* and the other two copies mentioned earlier, there seems to be a shift in the focus of the treatises from issues of personal interest to those of concern to the state officials of the Arsenal.[245] Moreover, they now seem to serve as a form of résumé for certain shipwrights, demonstrating their ability to build quality ships of a successful design.[246] The shipbuilding treatises could be utilized either within the Arsenal for employment or the rewarding of lucrative commissions, or as an example to other governments and private shipyards of a shipwright's aptitude in his craft. The Venetian Arsenal, however, would have benefited the most from the desire of shipwrights to produce quality designs in their treatises, by encouraging a sense of competition amongst the shipbuilders employed there.[247] In this context it is interesting to note that most of the 16th-century treatises are preserved in the state archives of Venice, deriving from the patronage of government officials, as opposed to the possession of the 15th-century treatises by wealthy collectors in prominent families.[248]

This new trend is personified well by the manuscript of Pre' Teodoro di Niccolò, the *Instructione sul modo di fabricare galere* composed sometime between 1550 and 1575. As a pupil of Francesco Bressan, the foreman of Arsenal shipwrights from 1540 to 1570, Pre' Teodoro enjoyed some fame for his designs of *galeone* that were completed under contract at the Arsenal.[249] The foreman shipwright Baldissera Drachio Quinzio, author of *La visione* (the Vision) in 1593, provides another instance of an Arsenal worker of some renown documenting his work. Drachio's treatise provides perhaps the most precise and clear explanation for the use of the *partison* method, described earlier, in

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245 Hocker et al. 2006, 10.
246 McManamon 2001, 25.
247 Ibid.
248 Hocker et al. 2006, 5.
249 Hocker et al. 2006, 6.

forming the master curve of a ship's hull.[250] The 1686 treatise *Architettura navale* (Naval Architecture), the last to be addressed, by the assistant to the foreman shipwright Stefano de Zuane de Michiel provides a far more comprehensive perspective on shipbuilding both inside and out of Venice. In addition to giving descriptions for the construction of a range of Venetian vessels, Stefano also comments on ships built in the shipyards of England and France, echoing the rising emphasis on the war-time ship of the line over the *galeazzza* warship traditionally favored in Venice.[251]

From the perspective of shipbuilding practices of, the corpus of Venetian treatises share some common traits. The first is that they exude a consistently didactic tone. The instructional purpose of these documents is evident even in the 14th-century *Zibaldone da Canal*, which does not address shipbuilding per se, but still aims to provide *l'amaistramento e la raxion* (instruction and methodology) in matters of merchant affairs.[252] The use of educational language is carried on in the MRMS and its various iterations, regardless of the topic being covered. These observations on the language of the treatises are also helpful in the more technical context of the prescriptions for shipbuilding. For instance, the particular and repeated use of the noun *raxion* (ratio) indicates much about the mentality of the authors and their perception of the conceptual method behind the shipbuilding craft.[253] The interchangeability of this term with the use of the word *rason* (method) in the context of the Latin *ratio* reflects an awareness of the ancient principles followed in order to acquire an aptitude in the skill under discussion.[254] The idea of a *rason* was extended to all aspects of the construction of a ship, while that of the *raxion* formed the basis for the proportional techniques espoused in the instructions for shipbuilding in the treatises. These characteristics were

[250] Hocker et al. 2006, 6.
[251] Hocker et al. 2006, 7.
[252] Hocker et al. 2006, 13.
[253] Hocker et al. 2006, 14.
[254] Ibid.

fundamental in the methodology of medieval ship construction and were pivotal in the transition to a more revolutionary way of thinking about the design of ships.[255]

[255] Dotson 1994, 163.

CHAPTER V
THE MICHAEL OF RHODES MANUSCRIPT

Before coming to the chapter in which a reconstruction of the *nave quadra* featured in Michael's text will be proposed, a more thorough examination of the contents of the MRMS will be offered. While the shipbuilding section will obviously be covered in detail in the next chapter, the other three main sections on topics of practical nautical information will be described here. These include the subjects of mathematics, navigation and time reckoning, all of which would have been necessary to the holistic knowledge of the medieval mariner. However, since the autobiographic portions about Michael's involvement in Venetian naval and mercantile affairs are such a prominent part of his text, they will first be discussed in adequate detail. Hopefully, this information will contribute to an understanding of the motivations behind the composition of this first treatise on shipbuilding.

It is apparent that Michael was concerned with the physical quality of his manuscript, as indicated by several expensive features. The doeskin binding is one such example. Another is the collection of richly colored illustrations found throughout the text that Michael commissioned from an illustrator.[256] The most impressive of these are full-page depictions of St. Christopher and a coat of arms, the latter of which includes a large Gothic "M" (perhaps a hint to the provenance of the material). Several stylistic and design elements illustrate Michael's pride in his Greek origins. The mirroring of page numbers, a +HIS+ invocation at the top of each page, and a twisted rope design to separate entries are all typical of Greek literature.[257]

A quick note should be made about the nature of the sources available for the MRMS and consequently for the following portions of this study. For a period of 120 years after the *Fabrica di galere* was so named by the French historian of medieval shipbuilding

[256] McManamon 2001, 23.
[257] Ibid.

Augustin Jal, it was unknown that the MRMS was still in existence, even though scholars were aware that the *Fabrica* was based on earlier material.[258] When Michael's text came up for auction in 1966 its identity was still unknown and it was not until another auction in 2000 that the manuscript was finally transferred from private ownership to the Dibner Institute for the History of Science and Technology for proper scholarly research.[259] Since 2003 a team of international scholars has been engrossed in the study and dissemination of the manuscript's contents, the result of which has been the creation of a comprehensive website. This, however, is currently the only source for the actual manuscript until a multi-volume publication originally slated for availability in 2007 is released. The quality of the information contained on the website, which is now hosted by the Institute and Museum of the History of Science, is superb, even offering the opportunity to view selected pages of the manuscript in its original form, as well as in its Italian transcription and English translation. Thus, the Michael of Rhodes website is a sufficient source for the study of the manuscript and certainly the reconstruction of the *nave quadra* described in its contents.

The Service of Michael of Rhodes and the Formation of His Manuscript

Of the Venetian shipbuilding treatises reviewed earlier, that of Michael of Rhodes is exceptional in the sense that its author had such extensive direct experience in the maritime affairs of Venice. His service spanned more than 40 years and covered positions from the lowest capacity as an oarsman to the most senior non-noble officer. Over this length of time Michael surely developed a greater interest in seafaring, which must have contributed appreciably to his desire to compile a manuscript on the topic, though a great deal of the material was borrowed from earlier sources. There are certainly other factors to consider in determining why this desire was present, however, and these will be addressed shortly.

[258] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_writing.html (2008, 8 July)
[259] Ibid.

Our knowledge of the life of Michalli da Ruodo, as his name is recorded twice in the manuscript, begins in 1401, with his enlistment as a *homo da remo* (oarsman) aboard a Venetian war galley in Manfredonia.[260] This city is located in the province of Foggia in Apulia, central Italy, near the remains of the ancient Greek colony of Sipontum and became an archdiocese in the early 11th century. Information about his life prior to this event is completely lacking, though one can infer that he was of Greek birth due to his name and the inclusion of Greek prayers in his text. No reasons are stated explicitly by Michael, however, for his decision to join the *varda* (guard) fleet of the Venetian Navy. The first ship that Michael served upon as a oarsman was captained by the famous commander Pietro Loredan, of one of the most prestigious families in Venice, who had been tasked with protecting Venetian grain ships around Manfredonia.[261] This relatively routine assignment would soon be eclipsed by Michael's involvement in a variety of important military engagements over the next three years aboard Loredan's galley.

The first such mission took Michael to Corfu, where his ship helped to fight the king of Naples for control of the island, which was an essential center for Venetian commercial enterprise.[262] Before finally making his way to Venice, Michael would make stops in Crete and then the major Venetian naval base of Modone. His stay in Venice would not last much more than a year before his ship was called upon to take part in the protracted altercation between Venice and one of its chief maritime rivals, Genoa. After hearing of news that the governor of Genoa, the French knight known as Maréchal Boucicault, intended to send a large fleet to Cyprus to put down a rebellion there, a guard fleet was dispatched in 1403 to ensure the safety of any Venetian ships and possessions on and around the island.[263] To add to the aggravation of the Venetians, Boucicault moved from his affairs in Cyprus to a series of raids on various Moslem seaports, some of which had warehouses containing Venetian merchandise.[264] Under the command of the

[260] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1401_1406.html (2008, 8 July)
[261] Ibid.
[262] Ibid.
[263] Ibid.
[264] Lane 1973, 199.

famous Venetian captain Carlo Zeno, the fleet essentially shadowed the movements of Boucicault, without engaging them, all the way to Rhodes. Zeno eventually engaged Boucicault near the Venetian base of Modon, sending him with only minor losses.

The Genoese attack on Cyprus was never actually carried out, but hostilities were rekindled when the Muslim city of Beirut was attacked shortly thereafter. Boucicault inflicted extensive damage upon Venetian mercantile interests in the city, destroying warehouses, looting and robbing goods and money and seizing Venetian ships in the harbor. Zeno reacted quickly by sending the galley under the command of the *sopracomito* (the noble captain of a military galley in the Venetian Navy) Andrea da Molin, on which Michael was aboard, back to Venice for orders.[265] In the meantime, Zeno embarked with the guard fleet to pursue and confront Boucicault. The two fleets met near Modone, with the Venetians achieving a decisive victory and Michael missing the battle by a day.

Though Michael apparently had no intention of quitting his service after the campaigns of 1401 to 1403, he did decide to take a temporary break from naval affairs when he enlisted as an oarsman on a merchant galley bound for Flanders in 1404.[266] This voyage afforded many new opportunities to Michael, including the chance to leave the Mediterranean for the first time and also to make a profit privately in addition to his salary. The right of merchant galley crewmen to carry their own duty-free goods for the purpose of trade was referred to as *portata*, while the amount of goods that could be brought was dependent on the rank of the individual.[267] Even on this initial journey to Flanders, of which there would be many subsequent ones, it is evident that Michael was influenced by the practices of the Venetian commercial system. Michael took a second

[265] Lane 1973, 199.
[266] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1401_1406.html (2008, 8 July)
[267] Ibid.

voyage with the Flanders fleet in 1406, this time as *proder* (a senior oarsman), though he would not make another commercial trip until 1411.[268]

After being promoted to *nochiero*, one of eight ship's apprentices, Michael returned to naval service in the Guard Fleet in 1407. This was a significant step up the ladder of command, which Michael documented with great pride in his manuscript, and certainly the first in an impressive series of honors bestowed upon him. The role of *nochiero* would have certainly been a formative period of Michael's maritime experience, as these apprentices were basically encouraged to learn as much as possible about shipboard operations.[269] Michael held this position for some time, from 1407 to 1413, serving on both military and merchant galleys. His military experience during this time was not nearly as eventful as that from 1401 to 1403, though he was involved in Venice's main goal of regaining control over the eastern coast of the Adriatic, which was no simple task. The highlight of this endeavor was probably the capture of Lepanto by the Venetians, home of one of the best harbors on the Gulf of Corinth and a highly contested area with the Turks. In 1411, 1412 and 1413 Michael repeated the commercial voyage to Flanders, though these trips would have been much more enjoyable in his new capacity as *nochiero*.[270] In an addition to an increase in his *portata*, Michael completed his apprenticeship in practical ship handling and mastered the basic elements of galley navigation.[271]

The next step up the hierarchy of officers was the position of *paron*, one of the three senior officers on a Venetian vessel. The duties of the *paron* at this time are somewhat unclear, as most of the information known about this position applies to pilgrim galleys of the late 15th century. However, if that information was consistent throughout the century, then the main responsibility of the *paron* was to oversee the outfitting and

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268 McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1407_1413.html (2008, 8 July)
269 Ibid.
270 Ibid.
271 Ibid.

provisioning of the ship prior to departure.[272] When the ship was underway the *paron* was in command of both the *nochieri* and the *homo da remo* seated in the forward part of the ship, in addition to being responsible for the bow anchors and possibly the sails.[273] The *paron* was also the first off the ship, so that he could manage the docking process and make arrangements with the appropriate local officials.

As *paron* in the guard fleet in 1414 and 1415, Michael took part in the conflict with the Ottoman Turks that would ultimately lead to the Battle of Gallipoli of 1416, in which Pietro Loredan was the commander of the guard fleet. Unlike the altercation with Boucicault's fleet in 1403, this time Michael and his ship played a more prominent role in the action, to the extent that the warship he was aboard was partly credited with the capture of the Turkish flagship and the slaying of its admiral.[274] Most likely for these actions and the capture of two Turkish *galleota* during the battle, Michael was given command of a Venetian *galleota* in 1419, which was a very rare honor for a non-noble like himself.[275] Two years before this occurrence he was even temporarily given the title of *homo de conseio* (man of the council) on another commercial voyage to Flanders. For the trip in 1420, however, he was dropped back down to *paron*. During his tenure as *paron*, following his return from service in 1415, Michael made note of a personal tragedy that befell him. This was the death of his wife, Dorotea, whom he had likely married shortly after his coming to Venice (by doing so he was granted basic Venetian citizenship rights).

From 1421 to 1434, when Michael completed his *zibaldone*, he held his highest position yet, that of *comito*. In this new capacity he would also make his first commercial voyage with the galleys of Romania, in 1421. At that time Romania was the area encompassed by the Byzantine Empire according to the Venetians.[276] On both commercial and

[272] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1414_1420.html (2008, 8 July)
[273] Ibid.
[274] Ibid.
[275] Ibid.
[276] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1421_1434.html (2008, 8 July)

military galleys, the *comito* was essentially the captain in the most practical sense, giving the crew direct orders and managing the course and direction of the ship. This applied also in the line of battle, where the *comito* was responsible for all necessary preparations and was generally in charge during the fighting. Following the one commercial voyage and the seven past voyages with the guard fleet, Michael received the highest promotion that he would get in his career. This was the title of *armiraio*, the highest office in the Venetian naval service that a non-noble could attain and one that Michael would hold in the years 1422, 1428, 1436 and 1440.[277] As *armiraio*, one commanded the entire fleet from aboard the flagship, being second only to the captain of the fleet. Unfortunately, personal tragedy struck again as Michael was enjoying his first year with this new honor, when his son Teodorino died while aboard.

Between 1421 and 1434, Michael shifted between commercial and military voyages, depending on current events. In both 1424 and 1425 he was sent as *comito* to attack Turkish fortifications and possessions in the areas surrounding Gallipoli and Salonika, first under the command of Pietro Loredan then Captain Fantin Michiel.[278] After the sack of Constantinople in 1204, Salonika was the biggest city in what remained of the Byzantine Empire outside of the capital. It and the large surrounding territory were acquired by Boniface of Montferrat and thereafter served as an important maritime center.[279] These military missions were followed by two consecutive commercial voyages, also as *comito*, in 1426 and 1427, in which on both occasions included a return to Salonika to deliver supplies to Venetian supporters. However, on both of these occasions the fleet was utilized more as a means of influencing the sultan to make a compromise peace by continually harassing the Turkish coasts.[280] Michael returned to the Guard in 1428 as *armiraio*, undertaking a mission under the command of Andrea Mocenigo that would last into the next year and in the process severely threaten the well

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[277] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1421_1434.html (2008, 8 July)
[278] Ibid.
[279] Lane 1973, 42.
[280] Lane 1973, 229.

being of his ship, his crew, and indeed himself.[281] The fleet was ordered to attack Gallipoli and attempt to retrieve Venetian merchant ships that were being kept in the harbor. After the plan of attack was finalized and begun, Michael's ship was abandoned by its escorts and barely escaped, signaling to the Turks a weakness in the command of the Venetian forces, and resulting in the eventual Turkish sack of Salonika.

Michael's final military exploits in 1431 and 1432, both involving serious battles, would take the heaviest physical toll on him of his career. The costliest was in a fight against the Genoese in 1431 as *comito*, once again under the command of Pietro Loredan, in which Michael was seriously wounded.[282] Despite his injuries, however, he undertook an unsuccessful mission to prevent the sack of Corfu and attacks upon Venetian interests throughout the Aegean by the Genoese in the following year.

Participation in commercial voyages during this phase in Michael's career included a trip to Flanders in 1430 as *homo de conseio*, preceded by first-time visits to Tana (in 1421 and 1427) and Trebizond (in 1426), both located in the Black Sea, and Alexandria (in 1433).[283] The year of the writing of his *zibaldone* witnessed another unique trip, this time to Aigues Mortes, the fortified port-city along France's Mediterranean coast.[284]

In the closing years of Michael's service in the Venetian Navy, from 1435 to 1443, he reached the peak of his career, only once serving in an office below *homo de conseio*. Most of this period was spent in a commercial capacity, though it was interspersed with special missions of a diplomatic nature. There were two more trips to Flanders, as *armiraio* in 1436 and *homo de conseio* in 1441, a trip to the Ukrainian city of Moncastro in 1435, again as *homo de conseio*, two journeys to London at the same rank in 1438 and 1443 and a third voyage to Alexandria in 1442.[285] While these were more or less routine

[281] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1421_1434.html (2008, 8 July)
[282] Ibid.
[283] Ibid.
[284] Ibid.
[285] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1435_1443.html (2008, 8 July)

commercial trips for someone with Michael's naval experience, a number of missions under the direct control of the Venetian state were of great significance in the geo-political climate of the time. Two of these tasks involved escorting Byzantine Emperor John VIII from Constantinople to Italy in 1437, and back to Constantinople in 1439. The intention of Emperor John VIII in visiting Italy during this period was to garner enough financial and military support to hold off the Turks, though he ultimately failed in his endeavor and Constantinople fell in 1453.[286] Michael's last mission was not of as great political importance as these two voyages. He was entrusted, as *armiraio* of the fleet, with delivering the Venetian wife of King Janus of Cyprus to her husband. This was nonetheless a very important diplomatic mission.

The remaining two years of the life of Michael of Rhodes were marked by a sequence of political failures, though the year of 1444 was fruitful from a historical perspective. It was at this time that he composed his second manuscript, the *Raxion de' Marineri* (Method for Mariners), which was basically a more concise version of his first manuscript due to the exclusion of several long sections. As mentioned earlier, this manuscript came into the hands of the Venetian sailor Pietro di Versi by unknown means, who erroneously claimed it as his own. At this juncture, though, the more pertinent path of inquiry concerns the writing of Michael's first manuscript.

Several hypotheses were posed in the previous chapter as to why shipbuilding treatises in general began to surface in 15th-century Venice, though the material they were based upon was written earlier. This question becomes somewhat more acute in the case of the MRMS, however, considering that the majority of the author's life is so well documented, particularly at the time it was written. It is important to keep in mind too, that the fact that the manuscript was written by someone of Michael's status in the first place is in itself exemplary. The production of books such as this was an expensive pursuit in many ways, including the cost of the paper and the pigments for illustrations,

[286] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_1435_1443.html (2008, 8 July)

in addition to the necessary manpower to complete the composition.[287] With Michael serving in the capacity of *comito* on commercial voyages, which by no means afforded him many personal luxuries, in 1434, it is worth speculating what would have obliged him to write the manuscript despite the expense and the effort.

Aside from an obvious personal interest in the topics covered in the manuscript and the possibility that it was ultimately intended as an extracurricular instructional guide for upcoming mariners in the Venetian Navy, the most compelling possible reason for Michael's authorship of the manuscript relates to his career interests. As alluded to earlier, the Venetian manuscripts likely served as a kind of *curriculum vitae* for shipwrights or other individuals involved in the maritime affairs of Venice looking to advance their careers. On the basis of this idea, Michael composed his manuscript with the intention of improving his chances at being promoted to either *homo de conseio* or *armiraio*, both of which he would have been qualified for at the time.[288] Despite this level of experience, though, Michael was competing mainly against native-born Venetian mariners of at least equal experience and skill, so his manuscript may have provided some extra advantage in this case. Perhaps the fact that Michael was elected as *armiraio* on the voyage to Flanders in 1436 can be seen as at least partly the result of this extra effort.

Nautical Knowledge of the Medieval Mariner

The section on mathematics in Michael's manuscript is the first and longest, reflecting not only his great interest in the topic but also its general usefulness in maritime affairs, particularly those of a merchant. The nature of the content in this section demonstrates Michael's awareness of the late medieval abacus tradition, where pen, paper and Arabic numerals were used to solve equations, and in which he was likely trained in the periods

[287] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/life_writing.html (2008, 8 July)
[288] Ibid.

between military and commercial voyages.[289] While Michael could have been tutored personally, he probably attended an abacus school where children of merchants and artisans were taught reading and writing, practical arithmetic, algebra and geometry.[290] Many manuscripts were produced by these schools, either as resources for teaching or as personal notebooks. The mathematical section of Michael's manuscript mixes both of these aspects, in which there is an effort to present both practical and theoretical information. Much of this is concerned with the use and manipulation of fractions, as well as algebra, which receives extensive treatment. The rule of three, used to solve many practical commercial problems, is also explained in detail and is used repeatedly throughout the text. The mathematical section is rounded out by several practice problems, most of them related to the activities of a merchant, but there are also more esoteric and complex examples.

A basic understanding of medieval mathematics was also necessary in the practice of navigation, which is addressed thoroughly in another section of Michael's manuscript. Incorporating some of the techniques mentioned in the mathematics portion is an explanation of the use of the *marteloio*, a method for recovering the course of a ship. This basically involved a mathematic technique for reckoning distance and direction at sea which utilized a series of rules applied to the contents of a pre-calculated trigonometric table.[291] The navigation section also includes three groups of *portolans*, the instructional sailing lists of distances and directions between ports along a coast, also indicating local landmarks and hazards.[292] The first group relates to the commercial voyage to Flanders, covering characteristics of the port of Venice and the English Channel, as well as several Atlantic harbors between these two points. The second group covers the coast of Italy from Manfredonia to Otronto, in addition to the Gulf of Salonika. The last group of *portolans* is found at the end of the manuscript and

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[289] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/math.html (2008, 9 July)
[290] Ibid.
[291] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/navigate_toolkit_basics.html (2008, 9 July)
[292] Ibid.

describes the route from Venice to Constantinople and Tana, plus the coasts and islands from Greece to Cyprus. The inclusion of these three groups of *portolans* reflect not only Michael's apparent interest in navigation from a mariner's perspective, but also the high level of experience that he had accumulated throughout his maritime career.

Utilizing techniques demonstrated in the mathematics and navigation sections, Michael also included an extensive description of the maritime practice of time reckoning. This part is divided into two sections. The first consists of several different tables, including a generic annual calendar featuring a list of martyrs and saints to be worshipped on each day of the year. There is also a wealth of celestial information, accompanied by a detailed illustration and description of the signs of the zodiac and three tables pertaining to the moon, though one of these is fraught with mistakes. The most important of these tables is the third one, a Table of Solomon providing the day, date and time of the new moon for every month of every year from 1435 to 1530.[293] This section also features several topics related to the *computus manualis*, a method of performing calculations involving the ecclesiastical calendar by counting on one's fingers, instead of using tables.[294] There is also a peculiar description of bloodletting, which includes notes on the potential results of this practice on certain days of the month. This is tied in to other astrological matters mentioned by Michael, namely the signs of the zodiac and their relationship to the different parts of the body.

As discussed previously, Michael may have been motivated to write his manuscript partly due to his ambitions of reaching a higher office in the Venetian Navy. Yet much of the information just covered, in addition to the section on shipbuilding, was not directly relevant to the practical demands of the offices that Michael sought. It would have certainly provided an impressive testament to the breadth of Michael's knowledge as a mariner, however, despite the fact that it was riddled with mistakes throughout the text. Moreover, as non-noble foreigner, the ability to provide evidence in support of

[293] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/time_tables.html (2008, 9 July)
[294] Ibid.

Michael's understanding and interest in topics integral to Venetian maritime traditions would have only strengthened his chances at advancing. This purpose should definitely not overshadow the apparent didactic intention of much of the information provided, which could have only been the result of a great personal interest and intellectual curiosity in all aspects of the maritime culture of Venice.

CHAPTER VI
A RECONSTRUCTION OF THE *NAVE QUADRA* OF THE MICHAEL OF RHODES MANUSCRIPT

The significance of Michael's *zibaldone* can be quantified in a number of ways. The fact that it contains the first extant example of a treatise on shipbuilding is certainly notable in its own right. This is of particular interest in the context of the changes taking place in the maritime sphere of the Mediterranean that were highlighted earlier in this study. With the fairly safe assumption that the material covered was derived from earlier sources, then the portions of shipbuilding are just nearly contemporary with the developments in sailing ships taking place as a result of the introduction of the northern European *cog* in the early decades of the 14th century. Both sides of this transition are represented in Michael's text, as he offers instructions for the building of both the traditional Mediterranean lateen-rigged ship, a *nave latina*, and the new square-rigged *cocha*.[295] Including the requirements for the construction of this latter vessel would have indicated an awareness and understanding of the newest nautical technology to other shipwrights and anyone else with an interest in maritime matters.

This is the basis for my choice to reconstruct the *nave quadra* instead of the *nave latina* or any of the oared vessels described in the manuscript. The *cocha* described by Michael, with its hybrid rig of a square sail on the mainmast and a lateen-rigged mizzenmast, was a sure harbinger of the full-rigged ship and arguably the most technologically advanced sailing vessel of the time. Furthermore, it was this innovation in sail technology that assisted the later voyages of discovery. By combining the better sailing qualities of the lateen sail with the labor saving benefits and easier maneuverability of a large square mainsail, the *nave quadra* exemplified the changes in ship design of the so called Nautical Revolution of the Middle Ages.

[295] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_sailing.html (2008, 10 July)

As stated earlier, the lack of any mention of shipbuilding experience in Michael's autobiographical journal likely indicates that he was not the original author of the shipbuilding treatise found in his manuscript. However, he must have possessed a fair amount of knowledge on the design and construction of ships, especially their fitting out for sea. It is certainly arguable that this was the intended purpose of the shipbuilding treatise in Michael's manuscript in the first place. With his experience in the capacity of *paron* prior to the completion of the manuscript, he was involved first-hand in the preparation and provisioning of his ship before departure. Thus he would have been closely associated with the fitting out of the ship as well and having the dimensions of the ship in hand would have assisted this task.

As with many of the measurements of the hull, the dimensions of the rigging components were determined proportionally. The mast, for example, was proportional to the maximum beam of the hull, while the length of the yard was in turn based on the height of the mast.[296] The incorporation of the descriptions of the various vessels, then, was a necessary precursor to explaining their outfitting. This concept is echoed by the material in other contemporary manuscripts, particularly that of Zorzi of Modon. In this case the author essentially states that a vessel cannot be rigged without first knowing the dimensions of the hull.[297] The outfitting aspect of shipbuilding was thus of vital importance, not only because of its obvious role in the operation of the vessel at sea, but also because of the considerable expense that was required. As this was the personal responsibility of the captain of the vessel, significant care was taken to keep costs low while maintaining the efficiency of the ship under sail.[298]

The text on shipbuilding in Michael's manuscript forms the second longest portion after that on mathematics and includes directions for the building of five different vessels. Three of these are galleys, each being a different type that Michael would have known

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[296] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_why.html (2008, 10 July)
[297] Ibid.
[298] Ibid.

well from his naval service, such as a Galley of Flanders, a Galley of Romania and a *galia sottil*, or light galley. As their names indicate, the first two were commercial galleys, while the third was a typical Venetian military galley of the guard fleet.[299] The discussions of all of these vessels follow the same basic formula, where specific hull dimensions are given first, followed by information on outfitting equipment and rigging. Illustrations of the completed vessels under sail are also included, showing detail of the rigging and sail arrangement, though the majority of the information concerning these aspects is located separately in the manuscript.

The last two vessels described are sailing ships, a *nave latina* and a *nave quadra*, the first carrying two lateen-rigged masts and the second a square-rigged mainmast with a lateen-rigged mizzenmast. Both are described in basically the same manner as the galleys, however there is a disparate amount of text devoted to each. While the *nave latina* is covered briefly, the *nave quadra* receives the longest treatment of any vessel in the text. Illustrations are unfortunately lacking for both sailing vessels, though a square-rigged ship is shown (fig. 1), but it is curiously equipped with only one square-rigged mast in the fashion of the northern European *cog*. Both vessels are characterized by a very basic and brief list of principal dimensions, consisting of the length on deck, the breadth and the depth in hold. At first glance it is somewhat surprising that these three measurements would have been sufficient for a medieval shipwright to build something as structurally complex as the *nave quadra*. However, from the perspective of the shipwright, these measurements formed the essential foundation for the ship and as such were the only necessary components in defining the shape of the hull. Since all dimensions were generally derived proportionally from one measurement, usually the maximum beam of the ship, having all of the hull's dimensions at the outset was not required.[300] Furthermore, given the technological limitations of shipbuilding at the time, it would not have been possible to project them before construction began anyway.

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[299] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_galleys.html (2008, 10 July)
[300] Lane 1934, 90.

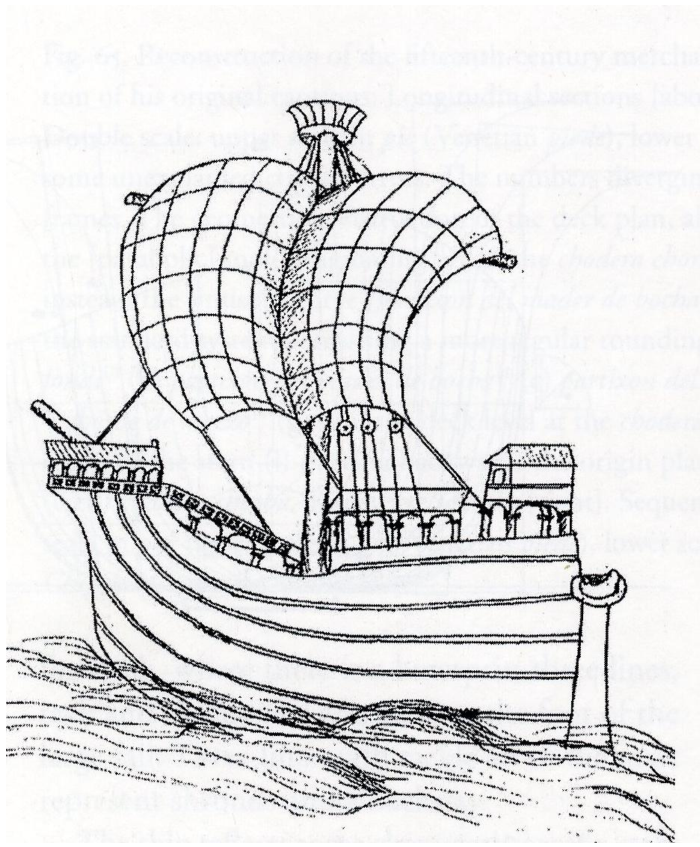

Figure 1: Square-rigged ship from the Michael of Rhodes manuscript (after Martin 2001, 86).

As a result, a number of problems are obviously posed for the task of attempting to reconstruct one of these vessels today, without the benefit of having the basic proprietary knowledge that would have made this possible in the past. Certain liberties must be taken, while attempting to maintain an appropriate level of historical accuracy which would not be necessary for reconstructing a vessel from an archaeological context. Without the presence of physical remains, much of what is proposed in this reconstruction will be speculative and will require the use of a variety of resources beyond the scope of the MRMS. For one, the more extensive information contained in the other Venetian shipbuilding treatises, especially the *Fabrica di galere* and the Trombetta manuscript, will be referenced and utilized to fill voids in Michael's descriptions. Since most of the shipbuilding information in the *Fabrica* and the other manuscripts was derived from the same source as the Michael of Rhodes text, there are many similarities that can assist this endeavor. However, emphasis will consistently be placed on the process of construction over the particulars of the ships structural characteristics, as sources are more plentiful and descriptive for the former aspect. Iconographic sources from Venice and surrounding areas, which are relatively abundant for the period in question, will additionally be consulted for the same purposes. Overall, with the corpus of evidence that is available, a fairly accurate overall reconstruction should be possible, to the extent that the sources permit.

Constructing the Basic Framework of the *Nave Quadra*

One of the first steps in building a vessel was to establish the dimensions of the hull.[301] For the sake of clarity before proceeding, one Venetian foot has been determined to be equal to 34.8 centimeters.[302] For the two-decked *nave quadra* of the MRMS the first detail given is the length of the keel (*longa in cholomba*), 13 Venetian paces or 65 Venetian feet (22.62 meters), whereas in the *Fabrica di galere* the beam measurement is

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[301] Steffy 1994, 93.
[302] Bellabarba 1988, 113.

given first, though it too arrives at a keel length of 13 paces.[303] This longitudinal timber was straight for sailing vessels such as the *nave quadra*, unlike the rockered keels of contemporary galleys.[304] Once the keel timber was felled and brought to the shipyard it was set up over a system of pilings for support.[305] The next step was to determine the placement of the master frame and the stem and sternpost, though Michael's text does not provide dimensions or directions for the setting up of the latter two timbers. The sternpost was generally straight and raked fairly steeply, though there was some variation in the degree at which it was fitted to the keel. For the square-rigged ship of the *Fabrica*, the rake of the sternpost (*slanzo de pope*) was calculated as five Venetian feet (1.74 meters) with a length (*longa l'asta de pope*) of 20 and two thirds feet (7.19 meters).[306] The sternpost was attached to the keel by means of a scarf, which was fastened to a heel at the end of the keel, or it was stepped directly onto the top of the keel.[307] Given that the *nave quadra* likely had an aftercastle, as indicated by the reconstruction of the *Fabrica nave quadra*, the stern probably had a flush transom, to which the straight stern-rudder could easily be attached.[308]

Whether the stem was curved or straight is unclear from Michael's text. His illustration of the *nave quadra* appears to indicate a slight curve to the stem, though the relationship between the attributes of this image and the *nave quadra* that is described is questionable due to the lack of lateen-rigged mizzenmast on the former. However, while northern *cogs* were traditionally characterized by their sharply raked straight posts, most iconographic evidence seems to indicate that the Mediterranean *nave quadra* would have been equipped with a curved stem (fig. 2). This is further supported again by the reconstruction of the *nave quadra* of the *Fabrica di galere*. For this vessel the length of the stem (*longa la roda de prora*) is calculated to be 32.5 Venetian feet (11.31 meters)

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[303] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_sailing.html (2008, 10 July)
[304] Bellabarba 1993, 276.
[305] Lane 1934, 89.
[306] Bellabarba 1988, 114.
[307] Steffy 1994, 96.
[308] Martin 2001, 159.

with a rake (*slanzo de prora*) of 22 and two thirds feet (7.89 meters).[309] The way in which the curve of the stem was determined is not described, though it probably followed a procedure similar to that for the stem of a galley, as explained in the Trombetta manuscript. In this case the curve was achieved by placing a triangle with its base extending from the keel scarf (*poselexe del choltro*) to the point where it crossed a vertical line indicating the point where the deck line met the stem (fig. 3).[310] Offsets were then taken from the base of the triangle to establish a fair curve for the outside of the stem, which in practice was probably drawn with the help of a flexible batten.[311] The overall length of the hull (*longa de roda in roda*) in the *Fabrica di galere* was calculated by applying a ratio of 3.6 times the beam, which yields a measurement of about 95 Venetian feet (33.06 meters).[312]

Having erected the keel and posts and secured them with the aid of posts on the sides of the hull, the next step was for the shipwright to determine the placement and shape of the master frame.[313] The location of this frame on top of the keel is unclear as far as can be detected from the manuscripts, though a position just forward or abaft of the center of the keel would not have produced a significant difference in hull shape in either case. The shape of the master frame was established by a series of measurements taken from the center of the keel to the inside edge of the frame and moving upwards from the floor to the upper deck [314] For the *nave latina* these are provided as fractional quantities based on the length of the keel, which was likely the same set of rules applied to the *nave quadra*.[315] The first measurement is the width of the hull at the flat position of the floor timbers (*de piano*), including their upturned ends, which is given as nine and three quarters feet (3.39 meters) for the *nave quadra* of the *Fabrica* manuscript.[316] The

[309] Bellabarba 1988, 114.
[310] Steffy 1994, 96.
[311] Bellabarba 1993, 276.
[312] Bellabarba 1988, 116.
[313] Steffy 1994, 97.
[314] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_design.html (2008, 19 July)
[315] Ibid.
[316] Bellabarba 1988, 113-115.

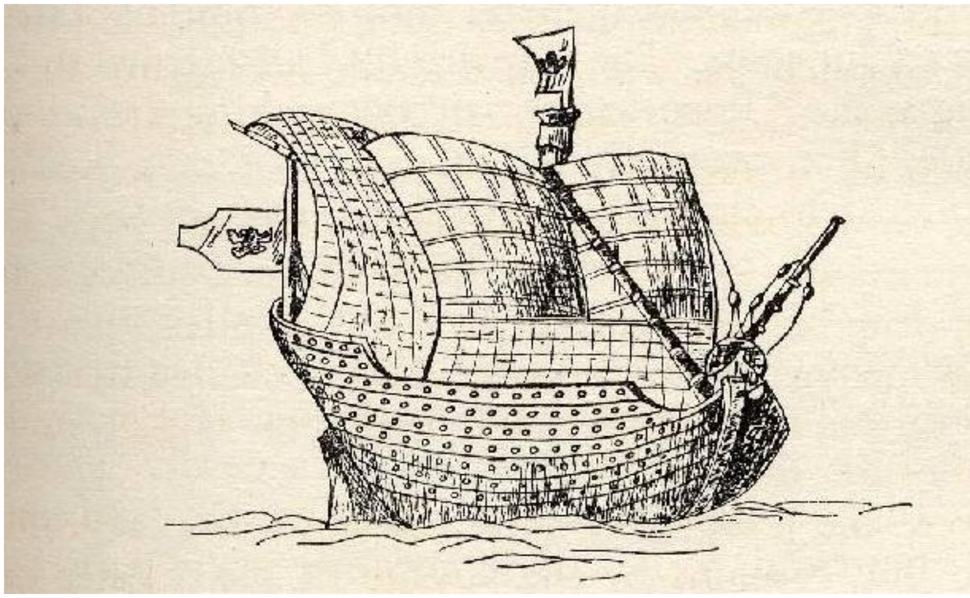

Figure 2: Two-masted Venetian *cocha* of 1366 (after Lane 1934, 43).

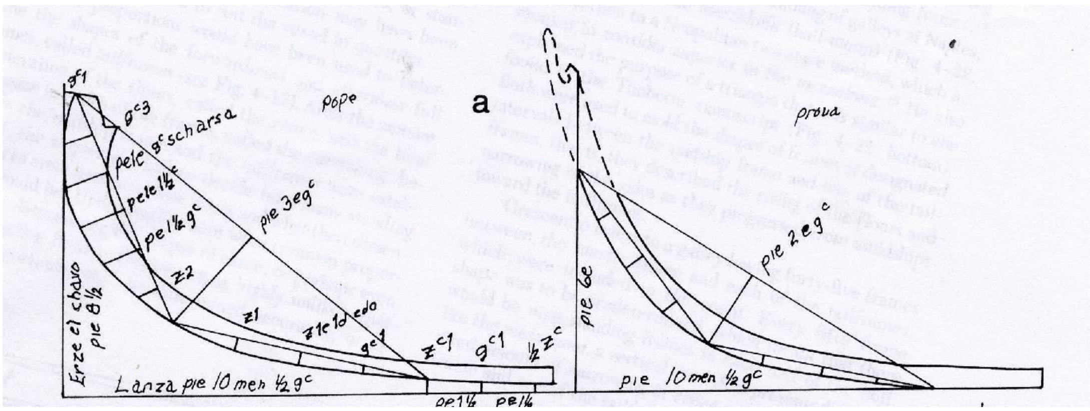

Figure 3: Stem (right) and sternpost projections from the Trombetta Manuscript (after Steffy 1994, 96).

Fabrica di galere gives the next measurements of the widths at three Venetian feet (1.04 meters) above the top of the keel (*de trepiè*) as 17.5 feet (6.09 meters) and the beam at the main wale (*de bocha*) as 26.5 feet (9.22 meters), though Michael's description gives a slightly longer value for the beam, at 27 feet (9.39 meters).[317] A value of 14 Venetian feet (4.87 meters) for the height of the upper deck is provided by both the MRMS and the *Fabrica di galere*, though the latter also gives the depth in hold (*erta in prima choverta*) and height of the second deck (*erta in la coverta di sovra*) as 7.5 and 5.5 Venetian feet (2.61 and 1.91 meters) respectively.[318] The remaining foot (34.8 centimeters) is composed approximately of the height of the floor timber (about 17 centimeters), the thickness of the deck planks (about 4 centimeters) and the height of the deck beam (about 13 centimeters).[319] A comparison of the key measurements of the *nave quadra* of the MRMS and of similar vessels described in the Trombetta manuscript and the *Fabrica di galere* will be provided in a table (fig. 4) on the following page.

Shaping the Hull of the *Nave Quadra*

With the four principal measurements (*de piano, de trepiè, de bocha* and the height of the upper deck) of the master frame established (fig. 5), its overall form could be transferred to a full-size mould and the shipwright could begin the process of defining the frames between midships and the posts, and thus the shape of the hull. Further moulds could be created to account for the addition of futtocks to the tops of the frame ends, though it is unknown how many were utilized for the *nave quadra* of the MRMS or the *Fabrica di galere* manuscripts.[320] On the other hand, since the futtocks for each frame were all possibly of the same basic shape, a single mould could be used for them, so only one additional mould would have been needed for the mainframe.[321] The Contarina I ship is the best-preserved nearly contemporary Italian vessel, and although it

[317] Bellabarba 1988, 113-115.
[318] Ibid.
[319] Ibid.
[320] Bellabarba 1993, 278.
[321] Bellabarba 1993, 280.

	MRMS	*Fabrica di galere*	Trombetta MS
Keel	22.62 meters	22.62 meters	24.36 m
Beam	9.39 m	9.22 m	9.74 m
Overall length	33.06 m	33.06 m	-
trepie	6.09 m	6.09 m	-
Width of flat floor	3.39 m	3.39 m	3.48 m
Depth of hold	2.61 m	2.61 m	-
Stem (length/rake)	11.31 m/7.89 m	11.31 m/7.89 m	12.53 m
Stern (length/rake)	7.19 m/1.74 m	7.19 m/1.74 m	7.31 m
Capacity	746 *botte*	705 *botte*	700 *botte*
Mainmast	32.38 m	32.28 m	34.1 m
Mizzenmast	16.14 m	16.14 m	-
Bowsprit	16.18 m	16.18 m	13.49 m

Figure 4: Comparison of the key measurements of the *nave quadra* of the MRMS, the Trombetta MS, and the *Fabrica di galere*.

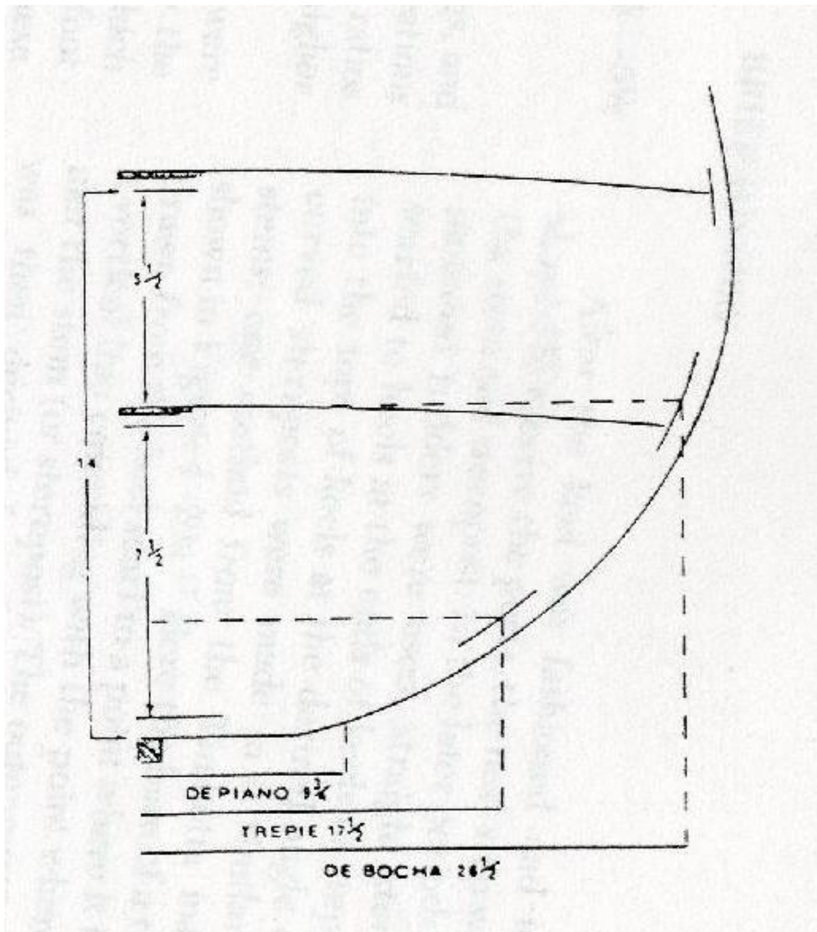

Figure 5: The mainframe of the ship of 13 Venetian paces keel length from the *Fabrica di galere* manuscript (after Steffy 1994, 94).

was a single-decked ship, and probably a *nave latina* type, it can give an approximate idea of the framing characteristics of a late-medieval ship of similar size to the *nave quadra* of the MRMS. It had two levels of futtocks for most of the central portion of the hull, thus it can be assumed that at least as many were utilized throughout the hull of the two-decked *nave quadra*, though this is only a working hypothesis.

With the positions of the keel, posts and master frame established, and the master frame mould(s) in hand, it was time to project the shapes of the other frames by means of ribbands. However, before these frames could be shaped, it was necessary to first set up another two control sections, placed at a certain distance from the master frame, named tail frames (*chodiera chorbe*). At least in the case of galleys, tail frames were needed to maintain the desired shape of the bow and stern sections by spreading and maintaining a fairly wide body of the ship over the central portion of the ship.[322] Moreover, the tail frames increased the breadth of the hull at the ends, which in a sailing vessel meant establishing the limits of the hull's useful internal space. Their position on the keel was usually determined by dropping a perpendicular line from a horizontal line extended between the stem and the sternpost.[323] With the tail frames in place, the ribbands were then extended around the standing framing components and once a fair curve or sheer for the hull was created, the shipwright could define the maximum quantities of rising (*stella*) and narrowing at the tail frames.[324] These two characteristics, described earlier, were the primary factors at work in the *partison* method, which dictated the gradual and incremental shaping of the floor timbers between the master frame and the bow and stern.

Before the master frame could be modified to establish the shape of the other frames, however, the shipwright had to decide how many standing frames were to be erected

[322] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_design.html (2008, 10 July)
[323] Lane 1934, 92.
[324] Steffy 1994, 97.

between the limits of the midship frame and each of the tail frames.[325] There is no indication as to what the prescription for the *nave quadra* was in this regard, though the Contarina I vessel gives a vague idea of this aspect. This ship was equipped with 29 standing frames towards the stern and 28 towards the bow, while fore and aft of these respectively, three and five unique forked frames without floor timbers were used to support the futtocks at the ends of the hull.[326] This would have given a total of 58 standing frames for a vessel with a keel more than six meters shorter than that of the MRMS *nave quadra*. Once the desired number of frames was determined, the next step was to decide how and at what increment of frames to apply the modifications of the *partison* method. This could vary depending on the period and the type of ship, as well as the taste of the shipwright. In some cases only the central portion of the hull was defined geometrically, being composed of four or five identical frames (*chorbe de mezzo*) in the example of a galley of the MRMS, with the bow and stern being shaped by use of ribbands.[327]

The specific aspects of the *partison* method were calculated and applied to the frames by means of two different geometric figures, as shown in the manuscript of Zorzi of Modon and described a century and a half later by Bartolomeo Crescentio in his study of galley construction at Naples.[328] The *mezzaluna* or half-moon figure (fig. 6) consisted of the semicircle CAD, with the vertical line AB representing the desired amount of narrowing or rising between the mainframe and either of the tail frames.[329] With each successive parallel line to CD representing the next framing station from the tail frame, the distance from A to each of these lines indicates the narrowing or rising increment for that frame.[330] This information was then transferred to and marked on some sort of ruler, termed *brusca* by Crescentio, which in turn was placed on the midship frame mould,

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[325] Steffy 1994, 97.
[326] Pryor 1999, 63.
[327] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_design.html (2008, 10 July)
[328] Pryor 1999, 63; Crescentio 1607,17, 68.
[329] Steffy 1994, 98.
[330] Ibid.

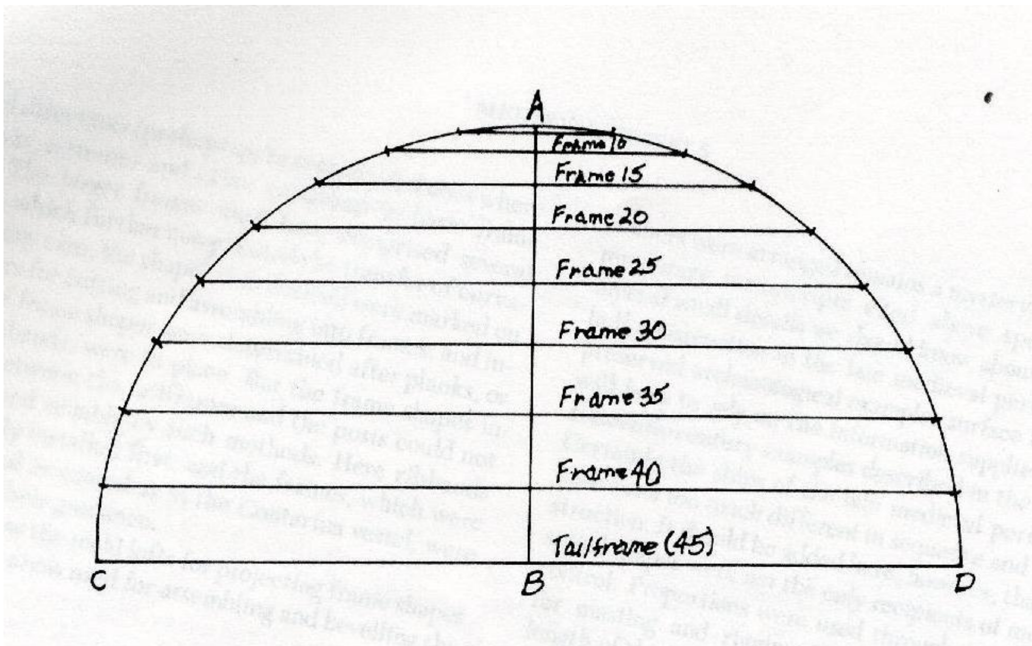

Figure 6: The *mezzaluna* geometric figure from the Trombetta manuscript (after Steffy 1994, 98).

with point A being located at the midpoint of the floor.[331] The marks of the *brusca* were transferred to the base of the mould so that the shipwright could proceed in shaping as many frames as were marked along line AB of the *mezzaluna*.

A kind of incremental triangle figure (fig. 7) was also described by Trombetta for the same purposes, at least the narrowing and rising, and may have produced more accurate and reliable results. The base of the triangle corresponded to the value of line CD of the *mezzaluna*, indicating the amount of narrowing or rising between the mainframe and either of the tail frames. Two lines of equal distance, the length being an arbitrary value, formed the sides, one or both of which were then marked incrementally at intervals following a given progression with the total amount of frames between the mainframe and tail frame.[332] Lines were then drawn at intervals parallel to the base at the marks which indicated the frames to be modified. In Trombetta's example he is dealing with a galley with 45 frames between the main- and tail frames, in which every fifth frame is to be altered. So nine parallel lines would be made, indicating every fifth frame, and in between these would be the marks for the 45 frames overall.

Two other modifications (or *partisoni*), involving the relationship between the shape of the futtocks and the frames, could also be calculated by means of the *mezzaluna* or incremental triangle figures. The first adjustment, the *partison del ramo*, consisted of adjusting the curve formed by the futtocks at deck level outwards to account for the loss of breadth due to the narrowing of the floor timbers (*partison del fondi*).[333] Consequently, the widening of the futtocks required an adjustment to the angle of the futtock to the floor, a process later described in England as haling down the futtock, but known in Venice as *scorer del sesto*.[334] It is unclear whether or not all four *partisoni* would have been applied to the *nave quadra* of the MRMS, as the process of construction is not described in the text. The Trombetta manuscript only mentions one

[331] Lane 1934, 95.
[332] Steffy 1994, 98.
[333] Bellabarba 1993, 281.
[334] Bellabarba 1993, 282.

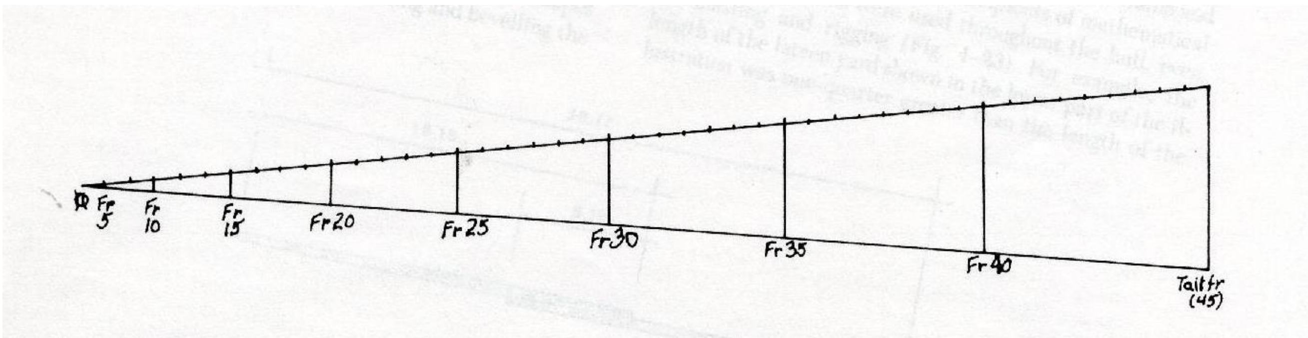

Figure 7: The incremental triangle geometric figure from the Trombetta manuscript (after Steffy 1994, 98).

partison in reference to each ship, though the term is generally mentioned on a number of occasions for both sailing ships and oared vessels, while the *Fabrica di galere* mentions the method only indirectly.[335] However, to what extent the *partison* method was utilized in practice in the first half of the 15th century remains unknown.

It is difficult to estimate the level of technological skill in terms of hull design possessed by early 15th century shipwrights, and whether or not they had the capability to utilize the techniques of the *partison* method to any degree. The inclusion of the geometric figures in the Trombetta manuscript indicates some awareness of these principles in Italian shipyards (used in Spain and Portugal in the late 16th century), though knowledge of their use comes from Crescentio's studies nearly 150 years later. Without these methods, the processes of design and construction for the *nave quadra* of the MRMS become far less distinct and the two in fact become one and the same. This notion returns to the idea of the ease of communication of shipbuilding techniques and the use of a limited amount of proportional rules to achieve the construction of a vessel like the *nave quadra*. Using just a few basic measurements and some simple proportional rules like those mentioned for the *nave latina* in the MRMS, a shipwright in a private shipyard could easily remember and construct such vessels.

However, as indicated by the instructions in the MRMS, the sequence of construction was dictated only up to a very fundamental point. Once the keel was laid and the posts and mainframe set up, the process basically moved forward at the discretion of the shipwright, with the dimensions of the remaining parts of the hull being derived from the evolution of the structure itself.[336] At the most basic level, this would have involved bending planks over the master and tail frames and then shaping the remaining frames to fit the planking.[337] However, aside from the terrific waste of wood this practice would have caused, it posed the disadvantage of significantly limiting the control that was

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[335] Bellabarba 1993, 284.
[336] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_design.html (2008, 11 July)
[337] Hocker et al. 2006, 2.

necessary to produce finer and more complicated hull shapes.[338] Where the MRMS *nave quadra* fits in terms of design and construction between this fairly crude method and the more advanced use of the *partison* system is difficult to know, though the use of basic modifications to the shape of the mainframe, such as the *partison de' fondi* (narrowing of the floor timbers), should not be excluded.

Hull Features and Attributes of the *Nave Quadra*

The construction process beyond setting up the frames is obscure for the *nave quadra* of the MRMS, which is also the case in the other Venetian shipbuilding manuscripts, probably because the finishing out of the hull was a relatively routine and straightforward task. Furthermore, since sailing vessels were typically built in the private shipyards of Venice where individual shipwrights would have had more leeway in the way in which they completed their ships, it may have been too impractical to try to standardize construction beyond the first basic steps. There is a great deal of material on several specific features of the ship and its equipment contained in the MRMS, the majority of which is dedicated to sails and rigging. Unfortunately, however, this information has yet to be disseminated and reliance must instead be placed on the information provided by the *Fabrica di galere* manuscript. Keeping in mind that much of this text was copied from Michael's manuscript in the first place, though, it is reasonable to assume that the two documents would have held much of the same information on the sails, rigging and equipment of the *nave quadra*.

The method by which tonnage was calculated will discussed before proceeding to these topics however. The basic formula was to multiply the beam measurement by the depth in hold (both in terms of Venetian feet), then multiply the product by the length of the keel (in paces) and divide the result by six.[339] For the *nave quadra* of 13 paces this

[338] Hocker et al. 2006, 2.
[339] Bellabarba 1988, 117.

yields a capacity of 746 *botte*, though a result of 705 is given in the *Fabrica* text.[340] The tonnage measurement of *botte* (or 'butts') was derived from a method of calculating capacity in Venice and Naples based on the size of an individual wine cask, established in the 13th century or earlier. In Venice one *botta* was equal to roughly 450 litres or 477 kilograms (one *milliarium*), though during the 14th century these quantities came to mean basically the same thing.[341] Based on the 15th-century Cretan cask of about 159 gallons, the new Venetian *botta*, which was the source of the standardized measure of a ship's capacity at that time, was equal to about 640 kilograms.[342] Overall, the *Fabrica* formula is fairly inaccurate for calculating capacity, consistently giving results for the ships listed in the Trombetta manuscript of between 16 and 40 percent over actual capacity.[343] Yet, very basic formulas like those described were generally used to assist the ship's carpenter in planning a ship before construction, much like the keel length. Since they do not indicate the specific points in the ship's structure that the measurements are to be taken from, they are too vague to calculate accurate capacity results.[344]

The first features that are discussed are the rudder and the ship's boats. As described earlier, with the introduction of the square-rigged *cog* came the use of the single stern-mounted rudder (*alla bavonesca*).[345] As opposed to the traditional Mediterranean dual quarter-rudders, the stern rudder yielded better overall control and greater ease of use. However, the use of the older steering device did persist for some time, even being used alongside the stern rudder in some instances, though this occurred more often on galleys.[346] For the square-rigged ship of the *Fabrica di galere*, the dimensions of the rudder are prescribed as being two Venetian feet longer than the stern post, with a width

340 Bellabarba 1988, 117.
341 Lane 1964, 222.
342 Lane 1964, 223.
343 Anderson 1945, 165.
344 Lane 1964, 226.
345 Martin 2001, 166.
346 Unger 1980, 182.

equal to a quarter of its length at its widest point (*all pala*).[347] These directions would give a rudder for the MRMS *nave quadra* with a length of 22 and two thirds Venetian feet (7.89 meters) and a width of about five and two thirds feet (about 1.97 meters) at the widest point. This last dimension would seem somewhat larger than expected, though this may have been necessary due to the use of one rudder instead of two.[348] The illustration of the square-rigged ship of the MRMS appears to confirm the size of the rudder described in the *Fabrica di galere*, as does the depiction of the 1,000 *botte* ship found in the Trombetta manuscript (fig. 8), but these should not be assumed to be overly accurate in terms of scale. This manuscript gives the width at the top of the rudder as one quarter less than the width at the bottom (about 1.48 meters) and additionally states that the tiller be as long as the rudder.[349]

According to the *Fabrica*, the rudder was attached to the sternpost by means of pintles and gudgeons, there being eight of each.[350] These were to be distributed according to the preference of the shipwright.[351] The method by which the stern rudder was maneuvered is unclear, though in both of the depictions mentioned above there is a sort of collar at the top which could have kept out water or simply provided reinforcement. On the ship of the Trombetta manuscript, on the other hand, the top of the rudder projects into the stern castle. The directions for the rudders on lateeners in the *Fabrica* indicate that they were controlled from a poop deck, due to the prescribed height of the rudder above the deck, which may suggest a similar arrangement for the rudder of the *nave quadra*.[352] However, since there is a lack of visual evidence of the steering devices of square-rigged vessels in most medieval iconography, this is difficult to prove either way.

The *nave quadra* was to be supplied with three ship's boats, according to the *Fabrica di*

[347] Bellabarba 1988, 117.
[348] Ibid.
[349] Anderson 1925, 152.
[350] Bellabarba 1988, 117.
[351] Anderson 1945, 164.
[352] Bellabarba 1988, 117.

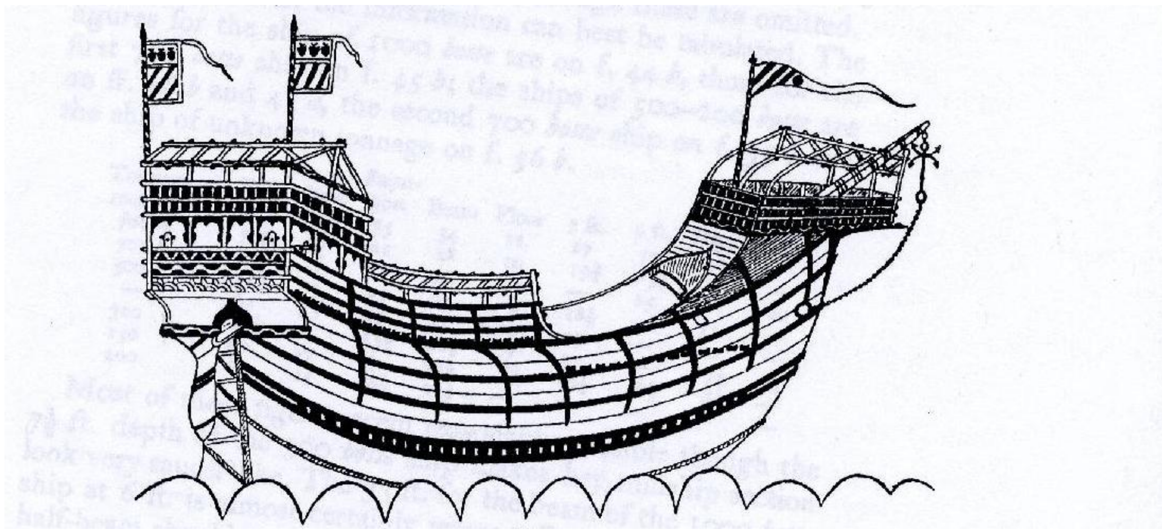

Figure 8: Stern-mounted rudder on the 1000 *botte* ship of the Trombetta manuscript (after Anderson 1925, 149).

galere, two of which were *batelli* and one a *gondola*.[353] The dimensions of the larger of the *batelli* are given as two-fifths of the length of the ship on deck plus one foot, or simply two feet long for every pace of the ship's hull length.[354] For the MRMS ship with a measurement from stem to sternpost of 95 Venetian feet (33.06 meters), this would be calculated as a length of 38 Venetian feet (13.22 meters), though it is given in the text as 36 feet. The smaller *batelli* was to be two paces shorter (12.53 meters) and the *gondola* 24 feet (8.35 meters) in length.[355] Following this information in the *Fabrica di galere* is a page and a half with no text except for the words *barcha*, *chopano* and *nave*, which were apparently intended to be the titles for illustrations of the ship and its boats.[356]

Following the discussion of rudders and boats, Michael's text then presents sections on the masts and yards and standing and running rigging. However, before delving into the extensive and detailed descriptions of these topics, we will examine the more briefly covered aspects of the anchors, the placement of the mast, the capstan, and ropes and lines for the rigging. This will allow all of the subjects related to the operation of the sails to be treated together, while those pertaining to the attributes of the ships' hull can be completely dealt with here.

The *Fabrica* manuscript gives some general rules for the size and amount of anchors and various cables for a ship with a keel of 13 paces, however the applicability of these guidelines depends on the type of ship described. Nonetheless, the ship was supposed to have 10 anchors and 12 anchor cables, assuming a tonnage of 700 *botte*.[357] In general, all anchor cables were to weigh 10 Venetian pounds (33.3 kg) per pace, with a length of 80 paces (139.2 meters), though this could vary. A certain level of ambiguity also extends to the characteristics of the anchors and mooring cables (*sartie d'acqua*), where

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[353] Anderson 1945, 164.
[354] Bellabarba 1988, 117.
[355] Ibid.
[356] Anderson 1945, 164.
[357] Bellabarba 1988, 118.

a number of fractional rules are dictated but rarely followed by the examples provided in the manuscript. Two different rules are given for determining the weight of an anchor, one stating that it should weigh 10 percent more than its cable, the other that it should weigh a quarter more.[358] However the weight was calculated, two of the 10 required anchors were 1000 pounders (3330 kg) and the rest 850 pounders (2830.5 kg).

The capstan is mentioned along with the information about anchors and mast placement, none of which is covered in detail. The text refers to the capstan as both *sguindazo* and *guindazo*, the slight variation possibly indicating a misspelling on the part of the copyist.[359] It is described as being about eight Venetian feet long (2.78 meters) with a diameter of 1.1 meters, yet these dimensions suggest that it would be too short to reach the first deck.[360] This has therefore raised the question of whether or not the author was instead referring to a windlass that would have been operated from the second deck. A capstan is actually depicted in the *Fabrica*, though it is in reference to the galley of Flanders and given the term *argano*, thus not lending any clarification to the original question.[361] The Trombetta manuscript does provide some information on the dimensions of the windlass, if this is in fact what the *Fabrica di galere* is describing. It states that it should be one half the length of the (main)mast measured in paces from the deck upwards, with a diameter (or circumference?) equal to its length plus one quarter.[362]

The positioning of the mainmast is covered prior to the above information in the MRMS text, however it is so briefly mentioned that it can be described here in only a few lines. The *Fabrica di galere* offers two different instructions for the placement of the main mast step without really clarifying to which ships each should be applied. One rule places the step at three-sevenths of the length of the deck from the bow (14.17 meters),

358 Bellabarba 1988, 118.
359 Bellabarba 1988, 117.
360 Ibid.
361 Bellabarba 1988, 118.
362 Anderson 1925, 151.

while the other puts it at two-fifths along the keel (9.05 meters from the bow), though the text claims that both rules can be used interchangeably.[363] When calculated this results in a difference of about 5.12 meters, which is by no means insignificant when considering the impact on the sailing quality of the ship that this discrepancy would make. While it is only speculation, the position at three-sevenths of the deck length appears more realistic for the *nave quadra* of the MRMS and the *Fabrica di galere*.[364]

The Rigging of the *Nave Quadra*

As is apparent from the text Michael devotes to the description of the *nave quadra*, his main concern was with details of the sailing apparatus, especially the square and lateen sails and the standing and running rigging. These features were among the most innovative aspects of the shipbuilding portion of the manuscript, this being the first known shipbuilding treatise with a description of the new arrangement of a square-rigged mainmast and lateen-rigged mizzenmast. Thus it is not overly surprising that Michael dedicated so much space to this subject. There are many similarities between the way in which the features of the hull and those of the rigging were conceived, namely the use of proportions to achieve the desired dimensions.

This is first evident in the length of the mainmast (*arboro de proda*), which was dictated by the *Fabrica di galere* to be three and a half times the maximum beam, equal to about 93 Venetian feet (32.28 meters).[365] On the other hand, this length is also given both as 99.5 feet and 18 paces and four and a half feet, though these may have been in reference to different ships.[366] The mainmast was fitted with a *calcet*, a separate square block of wood at the very top of the mast that held the lines for the shrouds.[367] The length of the *calcet* was one-fifth of the mast's length, at the most, while the width is shown as one-

[363] Bellabarba 1988, 118.
[364] Bellabarba 1988, 116.
[365] Bellabarba 1988, 119.
[366] Anderson 1945, 164.
[367] Anderson 2003, 111.

fifth of the *calcet's* length.[368] The length of the mizzenmast (*arboro de mezo*), from the deck up, was to be half the length of the mainmast, equaling about 47 Venetian feet (16.14 meters).[369] The directions for the diameter of the masts were the same no matter how they were rigged. The general rule being that, at their greatest width, they had to measure a half palm (one palm=24.84 centimeters) in circumference for each pace (one pace=1.74 meters) of length (one pace = seven palms).[370]

The length of the main yard was also derived from the main dimensions of the ship's hull, having to be three times the beam at 79.5 Venetian feet (27.67 meters), though a length of four-fifths (25.83 meters) of the mainmast is also suggested.[371] This yard was composed of two pieces (*pennoni*) of equal length (15.23 meters each), attached with an overlap of about 23 feet (8.02 meters), the diameter of which was seven-fifths of the length of each part.[372] The lateen yard of the mizzenmast was also made of two pieces, one being longer (*ventame*) than the other (*stelo*). The length was to be one and a quarter times the mizzenmast, equal to about 58 feet (20.18 meters).[373] The length of the *ventame* was seven-tenths of the total yard (14.13 meters) and one-third longer than the *stelo*, it being 6.05 meters in length.[374] A bowsprit was also found on the *nave quadra*, as equipped on northern European *cogs*, which served to hold lines that would keep the large square sail on the mainmast taut when going to windward.[375] The length of this yard is given as half the mainmast, 46.5 Venetian feet (16.18 meters), in the *Fabrica di galere* or one pace shorter than one of the *pennoni*, about 39 feet (13.49 meters), in the Trombetta manuscript.[376]

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[368] Bellabarba 1988, 119.
[369] Ibid.
[370] Ibid.
[371] Ibid.
[372] Anderson 1945, 164.
[373] Bellabarba 1988, 119.
[374] Bellabarba 1988, 120.
[375] Unger 1980, 140.
[376] Anderson 1945, 164.

Aside from a brief section on the manufacture of different rope types at the Venetian Arsenal, the next significant portion concerning rigging pertains to the cutting and making of sails. The dimensions of the square sail for the ship of 13 paces prescribed by the *Fabrica* manuscript are particular to that ship alone, though the general rules described for making and forming are applicable to any square-rigged vessel of the time. The square sail had a length at the head of 16 paces (27.84 meters), with the foot probably being slightly longer due to the curve it would have possessed.[377] The rise of this arch was calculated at a quarter foot per leech pace, or one-twentieth of the sail height.[378] The sail was composed of a layered matrix of cloth pieces (*fustagno*) and hemp reinforcement tapes (*binda* and *perzente*) of various thicknesses placed as grids and at spots of particular weakness or stress.[379] The perimeter of the sail was sewn with an array of reinforcements and attachment points for various rigging ropes. These consisted of *denti* (teeth) at the foot and *piedoca* (goosefeet), of which there were as many as 29 to help reinforce the points where several ropes were attached.[380] Four of these v-shaped reinforcements were placed on each side for the bowline bridles (*brancadelle*), while another six per side were reserved for buntlines (*quadernali e broil*) and clew lines (*stinchi*).[381] The remaining *piedoca* were centrally located on the foot of the sail, some being *piedoca di broil* and the others for ropes of an unknown purpose. The rope forming the perimeter of the sail, the bolt rope, was given a diameter of 3.3 centimeters at the head and 3.7 centimeters at the leeches and foot, with the rope itself forming the clews (the bottom corners) for the sheets.[382]

The square rig of the *nave quadra* exhibited a number of improvements over that traditionally found on the single-masted *cog*. For example, reef-points were discarded in favor of the exclusive use of bonnets, which could enable the sail surface to be increased

[377] Bellabarba 1988, 122.
[378] Bellabarba 1988, 125.
[379] Bellabarba 1988, 122.
[380] Bellabarba 1988, 123.
[381] Bellabarba 1988, 232.
[382] Bellabarba 1988, 124.

by lacing one or more of them to the foot of the mainsail.[383] One bonnet was located on each leech and was used on conjunction with a similar sail of slightly smaller size, the *quartarone*, though each type could apparently be used independently. Both the bonnet and *quartarone* extended a ‘cloth’ width beyond the side of the mainsail and were equipped with *binde, perzente* and *denti*. Of course the addition of the lateen mizzen sail (*vela per mezane*) was another improvement over the single-masted square rig of the *cog*, resulting in a profound increase in maneuverability, especially in and around harbours.[384] This sail was characterized by a pronounced curvature for the head and used *binde*, but not *perzente*, and other hemp reinforcement throughout the sail, especially at the clew (*pozal*). The foot of the mizzen sail was given no curvature, while, generally speaking, the angle of the head increased by a greater and greater gradient moving away from the peak, usually resulting in an angle of 18 degrees (*a terzo drappo*).[385] The Trombetta manuscript described this process, while offering diagrams for a variety of different lateen sail shapes, though these are not particularly accurate.

Standing and Running Rigging

The last significant components of the reconstruction of the MRMS *nave quadra* to be addressed are the standing and running rigging, the varying functions of which are not entirely clear from the Venetian manuscripts. In addition to the improvements in sail characteristics mentioned above, Mediterranean shipbuilders also added a more complex system of ropes, including lifts and a more advanced parrel, to enable better control of the large mainsail.[386] These innovations are mentioned in Michael’s text, though it is unfortunate that the illustrations that were intended to accompany this information were not completed.[387] They certainly would have clarified a number of matters, including

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[383] Unger 1980, 186.
[384] Ibid.
[385] Anderson 1925, 162.
[386] Unger 1980, 186.
[387] McGee et al. 2005, http://brunelleschi.imss.fi.it/michaelofrhodes/ships_sails.html (2008, 12 July)

the function of the multiple stays and types of shrouds discussed in the *Fabrica di galere*.

For example, there are two types of ropes, *frasconi* and *quadernali*, that were used as shrouds to support the mast.[388] However, these were also apparently used as pendants for carrying blocks for various kinds of tackles, which could serve to lift loads on deck or as running rigging.[389] According to the Trombetta manuscript, the *frasconi* were the foremost of the two rope types, three (two are prescribed in the Fabrica text) of which would have been located on each side of the mast as opposed to two of the *quadernali*.[390] Both were rigged with *menale* (runner tackles), the *frasconi* using two double blocks with 55 paces (95.7 meters) between and the *quadernali* using a double to single block tackle of 48 paces (83.5 meters).[391] The *frasconi* is connected to the tackle via a pendant (*coronella*) of five and a half paces (9.57 meters) and tie (*amante*) of 15 paces (26.1 meters), while the *quaternali* use a *coronella* of six paces two feet (11.14 meters).[392] For the *frasconi*, the thicknesses of the various ropes were 5, 4.6 and 2.6 centimeters for the *coronella*, *amante* and *menale* respectively, while the *coronella* for the *quadernali* was given a diameter of 3.7 centimeters.[393]

There were two types of ropes used solely as shrouds, called *senali* and *quinali*, the amount of which were typically given as equal to the number of paces the mast measured above deck.[394] Thus there were five *senali* and seven *quinali* on each side.[395] The only true distinction between the shrouds seems to have been their locations fore (*senali*) and aft (*quinali*), with the aftermost (*popesi*) sometimes being rigged with deadeyes (*bigote*) and lanyards (*menadori*) in a different manner than the *quinali*, which

[388] Bellabarba 1988, 225.
[389] Anderson 2003, 112.
[390] Anderson 1925, 157.
[391] Bellabarba 1988, 226.
[392] Ibid.
[393] Ibid.
[394] Bellabarba 1988, 225.
[395] Anderson 1925, 158.

used blocks (*taglie*) and runners (*menali*).[396] The *coronella* of the *senale* was slightly thicker (4.1 centimeters) and shorter (11.5 paces = 20.01 meters) than that of the *quinali* (3.9 centimeters diameter and 12 paces = 20.88 meters).[397] Both used *menali* (2.5 centimeters diameter) with double to single blocks, measuring 24 paces (41.76 meters) for the *senali* and 16 (27.84 meters) for the *quinali*.[398] Neither the MRMS, the *Fabrica di galere* nor the Trombetta manuscript mentions any rule for the number of stays (*stazi*) that were required for a mast of about 18 paces, as found on the *nave quadra*. Two are shown on the MRMS illustration (fig. 1). Nonetheless, the *stazi* were attached to the mast by means of stay pendants (*bragoti*), which measured from three to five paces (5.22 to 8.7 meters), and to the hull by deadeyes (*bigotte*), which were attached to iron collars and chains.[399] Length of each *stazi* is given as twice the mast at 36 paces (62.64 meters) with a thickness of 6.3 centimeters, with the *bragoti* being five Venetian feet (1.74 meters).[400]

For the most part, the standing rigging of the 13 pace *nave quadra* is fairly well understood from the descriptions in the *Fabrica di galere* and the Trombetta manuscript. The running rigging, on the other hand, contains many elements which are either unclear or still completely unknown. There are a number of ropes whose functions have been identified with some certainty, partly because of their similarities with the rigging of later, better documented, vessels. One such component is the ties (*amanti d'arboro*) for the mainmast, which on the 13-pace keel *nave quadra* were made up of two parts of equal thickness (6.3 centimeters), one consisting of two *rize* (pendants and collars), which were twice the length of the mast above deck, and the other of two *amanti* (the actual ties), the total length of which was twice the mainmast above deck (27.8 meters).[401] The Trombetta manuscript conversely gives the length of the ties as four

396 Bellabarba 1988, 226.
397 Bellabarba 1988, 227.
398 Ibid.
399 Bellabarba 1988, 226.
400 Anderson 1925, 158.
401 Bellabarba 1988, 229.

times the length of the mast.[402] The *rize* were given a length five times the greatest circumference of the main yard, indicating that, in addition to the yard collars, these would have formed pendants (1 to 2 times the yard circumference in length) with the ties laced to their ends via seized eyes.[403]

The description of the sheets (*scote*) and tacks (*contrascote*) is relatively brief, each of the former having a length one and a quarter times the length of the ship (41.33 meters) with a weight of 2 pounds for each pace of the mast.[404] The tacks and braces (*braze*) of the *nave quadra* are assumed to function in much the same way as described in shipbuilding treatises of the 17th and 18th centuries.[405] The parrel truss has been identified as the *legname d'arboro*, while the truss collar is called the *stropo del cholo* and the truss tackle the *anzolo* rope, which used two blocks and had a length of three times the mast above deck (41.7 meters).[406] The lifts (*mantichi*) are the last elements of the running rigging aside from those attached to the sail. The mast head held two stropped blocks to carry the lifts, though the number of blocks necessary for rigging the lifts is unknown.[407]

The final group of ropes associated directly with the manipulation of the sail includes the buntlines (*quadernali e broil*), clew lines (*stinchi*) and bowlines (*borine*). As discussed in the description of the square mainsail, v-shaped reinforcements called *piedoca* were integrated into the sail at various points to attach the ropes to. The buntline, for instance, was attached to the center of the sail foot and was the same length (or one and a half times) as the mast, with a thickness of 4.5 centimeters and three blocks, two single and one double.[408] The buntline was to weigh one pound three ounces per each palm of the

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402 Anderson 1925, 158.
403 Bellabarba 1988, 230.
404 Anderson 1925, 158.
405 Bellabarba 1988, 230.
406 Bellabarba 1988, 231.
407 Bellabarba 1988, 233.
408 Bellabarba 1988, 232.

yard's circumference.[409] The clew lines were attached to the corners of the sail foot, each having a length twice that of the mainmast from the deck up and a thickness of 2.5 centimeters. The leech lines (*scotine*) were of the same diameter and roughly the same length (two times the entire mast), requiring two blocks per side. The bowlines were the last ropes used to control the movement of the sail, each with a diameter of 2.5 centimeters and the same length as the clew lines and carrying one block per side to be stropped to the bowsprit. The buntlines were attached to the four *piedoca* on either side of the sail by means of the *brancadelle* (bridles) mentioned earlier, though according to the *Fabrica* text there were eight *brancadelle* per leech. All of the standing rigging was set up at the masthead, which had two shoulders for the rigging stop, in a particular order. Starting from the top, this consisted of the *sorda* (unidentifiable rope), *braze*, *scala*, *mantichi*, *scotine*, *quadernali*, *quinali*, *stazi*, *coronelle de'senali*, *coronelle de'frasconi*, *baonesi* (loading tackle) and *bulgare* and *minisieli* of the parrel.

There were many distinctions between the rigging of the mainmast and the mizzenmast. The latter did not have stays, though there were shrouds, consisting of 4 *quinali* and one *popese* on each side.[410] The *quinali* were made up of a *coronella* one-third the length of the mast (3.7 centimeters diameter) and a tackle with one single and one double block, while the *propose* had the same tackle and a *coronella* of eight paces (13.92 meters). For the running rigging, the mizzenmast had a double *amante*, the ties each being the same length as the mast with a diameter of 4.3 centimeters and attached to the yard by *rize*.[411] Unlike the mainmast, the mizzen likely had a halyard (*gomena* rope of eight times the length of the mast from the deck up) to lower the massive yard to the deck, assisted by four blocks (*chatani*), two being three-fold and two being double. A bowline (*orza*), composed of a pendant one pace in length and a runner of 14 paces, was responsible for holding the fore part of the lateen yard (*car*).[412] The function of the *morganali*, two pendants three paces long with a tackle of 24 paces in length, has yet to

[409] Anderson 1925, 159.
[410] Bellabarba 1988, 231-233.
[411] Bellabarba 1988, 233.
[412] Bellabarba 1988, 234.

be discovered, though in his *Archéologie Nautique* Jal posed the hypothesis that they were used to swing the yard from one side of the mast to the other.[413] There was also an *anzolo* rope, for the truss tackle, with a double and single block tackle, while the parrels had four *bolgare* and 16 *minisieli* plus two deadeyes. The last two components of the mizzenmast were the *suste*, most likely serving the same purpose as a martingale on later ships, and the *funde*, whose purpose is generally obscure on both the mizzen and mainmast.[414] The *suste*, each formed of a pendant two paces in length with a 24 pace long runner, were intended to maintain the shape of the sail by exerting downward force on the yard, thus they were attached at one-fifth the length of the *ventame*.

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[413] Bellabarba 1988, 234.
[414] Ibid.

CHAPTER VII
CONCLUSIONS

The examination of the two major transitions in shipbuilding methodology covered in this study demonstrates that such profound changes are invariably more complex than the evidence initially suggests. This is undeniably the case with the shell-first/frame-first debate, where each subsequent archaeological discovery has altered previous conclusions. Pivotal in this continuous evolution of thought has been the growing awareness of the mixed methods seen in vessels like the seventh-century Yassıada ship and the eighth-century Bozburun ship. The research of the remains of both of these ships has contributed greatly to the overall reworking of the original parameters of the shell-first/frame-first distinction. It is clear now that the original definitions expounded by this paradigm were far too restrictive and vague, though admittedly one can go only as far as the evidence permits.

Additionally, with a greater emphasis on the conceptual aspects of shipbuilding (many of them intangible steps that occur long before the first timber is laid) the scope of research has widened immeasurably. Ships are viewed increasingly as products of their particular time and place, as solutions to a specific group of problems confronted by the shipwright and ship owners.[415] With these considerations in mind, it is apparent that the generalities posed by the original framework for the shell-first/frame-first debate were insufficient. The notion of design and its role in the conception and execution of a ship is one subject that has been the beneficiary of recent research in early medieval ship construction. Originally thought to have been a development that paralleled the use of the frame-first method, ship design has more recently been detected in vessels built shell-first, though in a simpler manner than that utilized in the construction of medieval ships. The use of standards of measurement and basic proportions in the construction of the Bozburun and Serçe Limanı vessels are prime examples of such instances. Instead of being a direct

[415] Hocker et al. 2004, 8.

consequence of a new methodology, design can be seen as an integral component of the way in which a vessel is perceived. The idea of a change from the characterization of ships as longitudinally based to transversely based has been very instructive in this regard.

Similar to the development of construction techniques prior to the 11th century C.E., the adoption of the northern European *cog* and the changes in the rigging and other aspects of medieval sailing ship design has been subjected to gradual redefinition. For one, the traditionally accepted early 14th-century date for the introduction of the *cog* to the Mediterranean has been closely scrutinized and it has become increasingly clear that this date is far too late. Historical sources of the 13th century reference *cocas* or *coggones* brought into the Mediterranean at this time.[416] The adoption of the single-masted square-rigged ship has instead been suggested to indicate the point at which Mediterranean shipbuilders came to fully appreciate the advantages of this new type of vessel and thought it a practical alternative to the typical two-masted lateen vessel.[417] Besides the temporal adjustments that have been made, though, the parameters of the debate have once again been reestablished. For instance, the notion that the use of the square-sail nearly completely ceased after the Roman era has been widely scrutinized. Because this rig was so quickly adopted in the early 14th century, it likely remained in use throughout the Byzantine and early medieval periods.[418]

The emergence of comprehensive, sometimes eclectic, manuscripts on seafaring around the beginning of the 15th century is another integral aspect of the maritime history of the Mediterranean. From the perspective of shipbuilding, these documents represent a fundamental departure from the traditional conveyance of craft practices by means of apprenticeships or oral transmission alone. At first maritime manuscripts were intended primarily to satisfy the personal interests of individuals concerned with seafaring or

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[416] Friel 1994, 78.
[417] Unger 1980, 183.
[418] Bellabarba 1996, 82.

trade, and other associated topics, as exhibited in the 14th-century *Zibaldone da Canal*. While there is a didactic tinge to the material contained in this document, it is apparent that it was generally compiled as a kind of practical manual for the aspiring merchant.[419] Therefore ship construction, which was unlikely of any immediate concern to the typical medieval merchant, is not really touched upon.

With the appearance of the Michael of Rhodes manuscript, however, the concept of the merchant's manual evolved to include information on shipbuilding, while still containing the personal interests of the compiler. These interests were now more focused on specifically nautical themes, disregarding more general issues of merchant life. The tone of the shipbuilding portions in Michael's manuscript is decidedly different from that found in later Venetian treatises. Whereas these later examples were intended to provide the instructions necessary to construct and recreate a variety of Italian ship types, Michael's text includes such information without the same ambition. Without any form of experience in ship construction, in as much as no such knowledge is described in the biographical portion of his manuscript, it is likely that Michael copied the prescriptions for building and outfitting ships found in his text.[420] It is therefore reasonable to think that he did so with the hope of projecting a certain level of knowledge by demonstrating his awareness of the latest trends in maritime technology in order to assist his ascension up the hierarchy of the Venetian Navy.

Similar factors likely played a role in the motivation of shipwrights, usually in the employ of the Venetian Arsenal, to create the shipbuilding treatises of the 16th and 17th centuries. After the first quarter of the 16th century, such documents developed beyond their previous function as receptacles for the diverse knowledge of nautically-inclined individuals. Instead they became a type of shipwright's manual meant for circulation and consumption within the Arsenal. In this capacity they would have assisted greatly in the replication of specific ships, both naval and commercial, for the shipwrights and their

[419] Dotson 1994, 11.
[420] Hocker et al. 2006, 10.

work force.[421] The fact that most of the prescriptions for ships found in the treatises were accompanied by technical drawings attests to their purpose as a means of propagating successful designs. Overall, shipbuilding treatises were no longer concerned with matters of personal interest but with matters dictated by the leadership of the Arsenal. As a result, a more focused approach to shipbuilding was being cultivated, consequently advancing the craft into an increasingly formulaic and efficient pursuit.

However, this crucial step in the development of the intellectual aspect of medieval shipbuilding probably could not have taken place without the creation of a manuscript such as Michael's. Even despite his lack of any formal education in contemporary shipbuilding methods, Michael's inclusion of data on ship design and construction in his treatise represents an important juncture in Mediterranean shipbuilding. That this data forms the first known extant treatise on shipbuilding is itself significant, though there is no single satisfactory explanation for its existence in the beginning of the 15th century.[422] The discovery of the original manuscript from which the shipbuilding portion of Michael's manuscript was copied would of course help to illuminate this matter greatly. Nonetheless, it is reasonable to postulate that since there is archaeological evidence that the *partisan* method had been in use for several centuries prior to Michael's manuscript, someone had likely thought it prudent to record such information in that long period of time.

For the development of ship construction methods in the Mediterranean, particularly those pertaining to sailing vessels, the Michael of Rhodes manuscript demonstrates several important points. Firstly, from the perspective of design, the nature of the prescriptions for the construction of each type of vessel in the treatise poses a unique solution to the problem of recording and transmitting the necessary instructions in a clear and succinct way. Design in the strictest sense was still not employed, meaning that shipwrights did not yet possess the ability to predetermine the dimensions and placement

[421] Dotson 1994, 163.
[422] Hocker et al. 2006, 3.

of each part of the entire ship. On the other hand, construction was no longer achieved purely as a result of the continuous input of the shipwright, during which adjustments were made by eye and based on his knowledge and experience. Instead, the method of ship construction described in Michael's treatise is a sort of compromise between the two just mentioned, indicative of the period of transition that this thesis describes. As covered earlier in this study, this system consisted of building a ship based on a set of proportions for key parts of the hull like the keel and stem and sternposts. The salient point to remember, though, is that the construction of a significant portion of the ship still depended on the skill and knowledge of the shipwright and his ability to "design" as he went.

Aside from these aspects of the development of ship construction techniques, the Michael of Rhodes manuscript illustrates several other integral points about medieval maritime culture. As this study has demonstrated, this document is a valuable resource in tracing not only the evolution of shipbuilding methods in the Mediterranean, but also in supplementing the void of archaeological evidence for this period of time. With the overall lack of medieval shipwrecks, thorough examination of the available literary evidence is that much more crucial to the understanding of the transitions taking place in nautical technology, particularly in Italy. As the earliest known example to include a shipbuilding treatise, the 15th-century manuscript compiled by Michael of Rhodes provides a natural place to begin this investigation.

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